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Fabric Filter System Study
Second Annual Report

Southwestern Public Service Co.
Amarillo, TX

Prepared for

Industrial Environmental Research Lab.
Research Triangle Park, NC

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Fabric Filter System Study: Second Annual Report

by

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Contract No. 68-02-2659
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Research Triangle Park, NC 27711

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16. ABSTRACT The report describes the second year's activities of a comprehensive EPA-funded study of a commercial fabric filter on a 350-MW low sulfur coal-fired unit at Southwestern Public Service Company's Harrington Station, near Amarillo, Texas. Special tests were performed to characterize gaseous and particulate emissions, to evaluate fabric performance, and to optimize the fabric filter system's performance. Tests will continue. Test results confirmed that the unit can operate in compliance with the existing New Source Performance Standard (NSPS) of 0.1 lb/million Btu. Because NOx concentrations were consistent at all five sampling locations, NOx will be excluded from future testing. Test results from the stack indicated that the unit can meet existing NSPS for SO2; results correlated well with stoichiometric calculations. During other tests: mass emissions of particulate measured at the stack ranged from 0.007 to 0.034 lb/million Btu; average particulate collection efficiency was about 99.3%; the mean particle diameter was 5.4 micrometers at the stack exit; SO2 emissions were within NSPS of 1.2 lb/million Btu; NOx emissions were consistent across the entire baghouse; and SO3 emissions ranged from 0.3 to 3 ppm.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Nitrogen Oxides	Pollution Control	13B	
Filtration	Fly Ash	Stationary Sources	07D	21B
Fabrics	Electrostatics	Fabric Filters	11E	20C
Dust		Particulate	11G	
Aerosols				
Sulfur Oxides			07B	

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ABSTRACT

This report describes second year activities of a comprehensive EPA-funded study of a commercial fabric filter on a 350 MW low sulfur coal-fired unit at Southwestern Public Service Company's Harrington Station near Amarillo, Texas. Special tests were performed to characterize gaseous and particulate emissions, to evaluate fabric performance, and to optimize the fabric filter system's performance. Tests will continue during the third year of study.

This report is submitted in fulfillment of Contract No. 68 02 2659 by Southwestern Public Service Company under the sponsorship of the U. S. Environmental Protection Agency. This report covers the period October 1, 1978 to October 1, 1979.

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CONVERSION TABLE

To Convert From	To	Multiply by
Btu/lb	joules/kg	4186.8
^oF	^oC	(°F-32)/1.8
ft	m	0.305
gr/scf	gm/m^3	2.29
in.	cm	2.54
in w.g.	mm Hg	1.87
lb	gm	454
miles	km	1.609
oz.	grams	28.350
ppm	mg/liter	1.0
Btu	joules	1055
cfm	cubic meters/hr	1.699
ft/sec	centimeters/sec	30.48
sq. ft.	sq. meters	0.093
lbs. of tension	newtons	4.448
stack pressure in Hg	kg/cm^2	0.035
$wscf/10^6$ Btu	wscm/joule	$2.6x10^{-11}$
$lbs/10^6$	nanogram/joule	433.3
lbs/wscf	$micrograms/m^3$	$16.018x10^8$
ft^2	$meters^2$	0.093

I. INTRODUCTION

The second year of work on the Fabric Filter System Study being conducted by Southwestern Public Service Company for the U.S. Environmental Protection Agency (EPA) ended October 1, 1979. The objective of this project is to make a comprehensive study of a fabric filter system (FFS) used for particulate collection on an electrical generating unit that utilizes low sulfur, Western coal.

Southwestern Public Service Company (Southwestern) is an electric utility headquartered in Amarillo, Texas. The Company has a generating capacity of 2,921,100 kW and serves customers in Texas, Oklahoma, New Mexico, and a small area of Kansas. Harrington Station, where the study is being performed, is Southwestern's first coal-fired plant. Located 5 miles northeast of Amarillo, Texas, Harrington went into operation in July, 1976, with one unit on line.

Project activities during the second year of study progressed from the first year's organizational stage (described in the First Annual Report [1]) to actual testing and evaluation. The first set of special tests was conducted by Southwestern and GCA, Southwestern's subcontractor, a fabric assessment program was implemented, and a wide range of operation and maintenance tasks were completed. In addition, a data acquisition system was established and certain study areas were given special consideration.

The FFS at Harrington Unit 2 is a Wheelabrator-Frye Inc. structural baghouse with deflate and shake cleaning. It first went on line in June, 1978. The baghouse consists of 28 compartments with 204 bags per compartment for a total of 5,712 bags; each bag is 11½ inches in diameter and 30 feet, 8 inches long. The baghouse was specified to operate at 1,650,000 acfm of flue gas at 313°F, thus yielding an air-to-cloth ratio 3.15 to 1 (gross) or 3.4 to 1 (net).

Unit 2, on which the FFS is installed, has a 360 MW turbine with a tangentially-fired steam generator. The boiler utilizes pulverized low sulfur Western coal to produce 2,688,000 lbs/hr of steam. The fly ash laden flue gas from the boiler flows through the preheater directly through the FFS and then out the stack.

II. SUMMARY AND CONCLUSIONS

1. To characterize gaseous and particulate emissions from the boiler/baghouse system, Southwestern conducted a series of special tests during December, 1978. Results of particulate testing confirmed that Unit 2 can operate in compliance with the existing New Source Performance Standard (NSPS) of .1 lb/10^6 Btu. However, problems in the testing with the heated probe caused results to be biased (high). Concentrations of NO_x were determined to be consistent at all five sampling locations. As a result, Southwestern and EPA decided the testing program could be better managed by excluding NO_x from future testing. Test results from the stack location indicated the unit can meet existing NSPS standards for SO_2 and results correlated well with stoichiometric calculations. SO_2 measurements at inlet locations were erratic due to high negative duct pressure.

2. GCA Corporation conducted extensive tests from February 9, 1979 through February 15, 1979. Mass emissions of particulate were conducted at the stack location with five sampling runs. Mass emissions ranged from .007 lbs./10^6 Btu to .034 lbs/10^6 Btu. Average particulate collection efficiency was determined to be approximately 99.3%.

   Particle size distributions were made utilizing Anderson impactors. The mean particle diameter was determined to be 5.4 microns at the stack exit. The mean particle diameter for the east and west inlet was determined to be

3.8 and 2.6 microns, respectively. Due to erratic data scatter, further testing by impactor is recommended.

Sulfur dioxide emissions were within NSPS of 1.2 lb/10^6 Btu. However, the results were erratic, probably due to high negative stack pressures. Oxides of nitrogen emission were consistent across the entire baghouse.

Results of sulfur trioxide testing ranged from 0.3 to 3 ppm. To obtain a better measurement and to better understand SO_3 concentrations and their relationship to acid dew point, a Goksoyr-Ross test will be performed during the next series of tests.

Difficulties encountered during organic emission sampling prevented a conclusive analysis of this data during the second year of study. GCA's final report will deal with this parameter in a more complete manner.

3. During the second year of study, Southwestern implemented a fabric assessment program in which individual bags were removed from compartments at random and sent to an independent testing firm for evaluation. This phase of study will continue in the third year to determine if such tests are useful in evaluating bag performance and bag life.

4. Another special study was initiated between Southwestern and Wheelabrator-Frye, Inc. This study was designed to determine distribution of ash on bags in a given compartment and differences in particle size distribution in the compartment and along the fabric. Preliminary results of these tests show that the bags receive equal dust loading regardless of position in the compartment. Furthermore,

indications are that both dust loading and particle size do not change significantly along the length of the bag.

5. An additional fabric assessment program was conducted by Acurex Corporation utilizing a small mobile baghouse. Recommendations made to Southwestern following this study were that Southwestern should evaluate the performance of an Acid Flex coating and performance characteristics of higher deflation pressures with ringed bags. Acurex also recommended higher shake frequencies, confirming results of previous tests done by Southwestern.

6. Southwestern developed a technique for analyzing individual compartment performance by measuring relative flow. This technique allows data taken at any flow condition to be compared with data taken at any other set of flow conditions. Results to date have indicated this technique to be a reliable and sufficiently accurate method for measuring compartment performance.

7. Improved performance was obtained during the second year of study by optimizing deflation pressure drop and shaker speed. As a result, deflation pressures were attenuated from the initial 0.5-inch w.g. to 0.1-inch w.g. Excellent results were obtained by increasing rapidity of shake in several experiments. Studies are in progress to determine the effect of increased shake on bag life. Preliminary results to date indicate that there is no drastically detrimental effect on bag life.

8. Originally, pressure drop in the baghouse was excessive. Since rebagging with different bags, optimizing deflation control, and increasing shake speed, baghouse performance has been greatly improved.

9. A data collection and assessment program was initiated during the second year of study. However, due to a faulty magnetic tape system, appropriate data processing has not been possible so that data can be easily reduced and analyzed. An intense effort will be made in the third year of study to manually reduce much of this data. In addition, a new magnetic tape system will be installed.

   Due to concern about high pressure drop problems, much of the ΔP data was manually processed to give monthly values for the full load pressure drop. Plots of full load pressure drop for each month have proven to be an invaluable tool in assessing trends in baghouse performance.

10. A special study area of the EPA/Southwestern project includes corrosion testing, electrostatics, and quality assurance (QA). Corrosion coupons were installed and then removed for analyses during the second year of study. Results indicate that corrosion in the Harrington baghouse at this point is minimal. Cage voltage measurements made by Acurex during the mobile baghouse study led to a decision by EPA to initiate a program with Research Triangle Institute to study electrostatics and its relationship to pressure drop problems. Efforts will continue during the third year of study to develop a QA program.

III. SUMMARY OF TEST PROGRAM

A. First Special Test

A major objective of the Southwestern/EPA study is to characterize gaseous and particulate emissions from the boiler/baghouse system. To accomplish this objective, a series of special tests are specified in the project Scope of Work to measure mass emissions of particulate, sulfur dioxides and oxides of nitrogen. The first special test was scheduled for October, 1978. However, due to delays in reaching a typical operating level for the FFS, testing was postponed until December. In the third year of the study, special testing by Southwestern will be performed three more times.

The magnitude of the special testing program created a need for additional project personnel on a temporary basis. Only a few Southwestern employees had actual hands-on, stack sampling experience; therefore, it was necessary to "recruit" personnel from other power plants on Southwestern's system, the System Lab, the Plant Design Department, and the Environmental Branch. A total of 22 people made up the first special testing team. An orientation session was held at Harrington Station before sample collection got underway. Personnel with experience in stack sampling were designated "team leaders"; a "Pre-Test Training Manual for Baghouse Study Testing" was given to those who had no previous stack sampling experience. Basic instructions in test procedures and equipment handling were also presented during the orientation session.

The first special test required five days to complete. Southwestern anticipates that future tests will be done in less time, due to the experience gained during the first special test. An effort will be made to use the same personnel for each series of tests.

Hourly coal samples were obtained from each coal mill during the special testing period. Samples were taken to the Harrington coal preparation area and combined into a composite sample. The composite sample was then sealed in a plastic bag and sent to the System Lab. Some selected groups of samples were sent to an independent testing lab for verification of the the System Lab's test results. A representative coal analysis for samples collected during the first special test is shown in Table III-1.

The equipment used for the special testing included the following:

1. Sampling Consoles: The System Lab has five sampling consoles. Three of them were purchased from Lear Siegler and were manufactured by Napp, Inc. A general representation of the Lear Siegler consoles is given in Figure III-1. The two remaining consoles were fabricated by System Lab personnel and are similar in design to the Lear Siegler units, except that the pumps are not mounted inside the console. The pumps are plumbed as shown in Figure III-2.

2. Probes and Probe Liners: The System Lab has a total of six probes. Four of these probes are used for baghouse testing and have 316 stainless steel liners; each liner is 1/2-inch outside diameter (OD). The two probes used for inlet testing are 22 feet long, the two outlet probes are 32 feet long. The probe used for testing the Unit 2 stack is 12 feet long. The assembly of the probes is shown in Figures III-3 and III-4. The other two probes are for stack testing and each has a 5/8 inch OD Inconel liner.

Probe liners have an 18/9 male ball joint on one end. The liners are wrapped twice with fiberglass tape, then elec-

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Table III-1. REPRESENTATIVE COAL ANALYSIS

BLACK THUNDER MINE
CAMPBELL COUNTY, WYOMING

Based on April 10, 1975 statistical analysis of 140 core holes

PROXIMATE ANALYSIS - As Received

	Typical	Range
Moisture	28.26%	22.59 - 34.52
Ash	4.74%	3.69 - 8.79
Volatile	32.00%	27.39 - 38.04
Fixed Carbon	35.00%	30.96 - 40.02
	100.00%	
Btu/lb	8700	7765 - 9203
Sulfur	0.33	0.09 - 0.59
SO_2/M Btu	0.77	0.20 - 1.37

ULTIMATE ANALYSIS - As Received

	Typical	Range
Moisture	28.39%	23.40 - 34.52
Carbon	50.03%	45.26 - 53.70
Hydrogen	3.54%	2.84 - 4.13
Nitrogen	0.69%	0.41 - 1.02
Chlorine	0.01%	0.00 - 0.16
Sulfur	0.33%	0.09 - 0.59
Ash	4.73%	3.69 - 6.64
Oxygen	12.28%	10.25 - 15.00
	100.00%	
Equilibrium Moisture	24.76	19.23 - 27.33
Btu at Equilibrium Moisture	8840	8578 - 9770
Hardgrove Grindability Index	53.27	37.00 - 67.80

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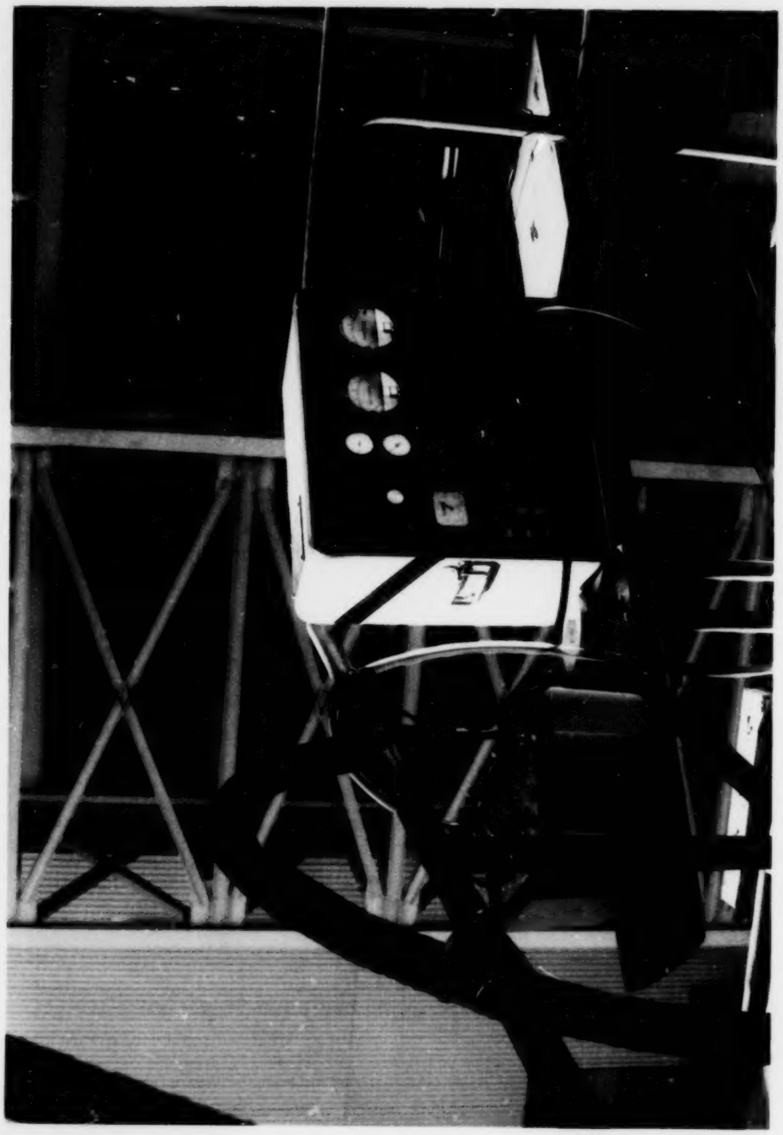

Figure III-1. Lear Siegler Consoles.

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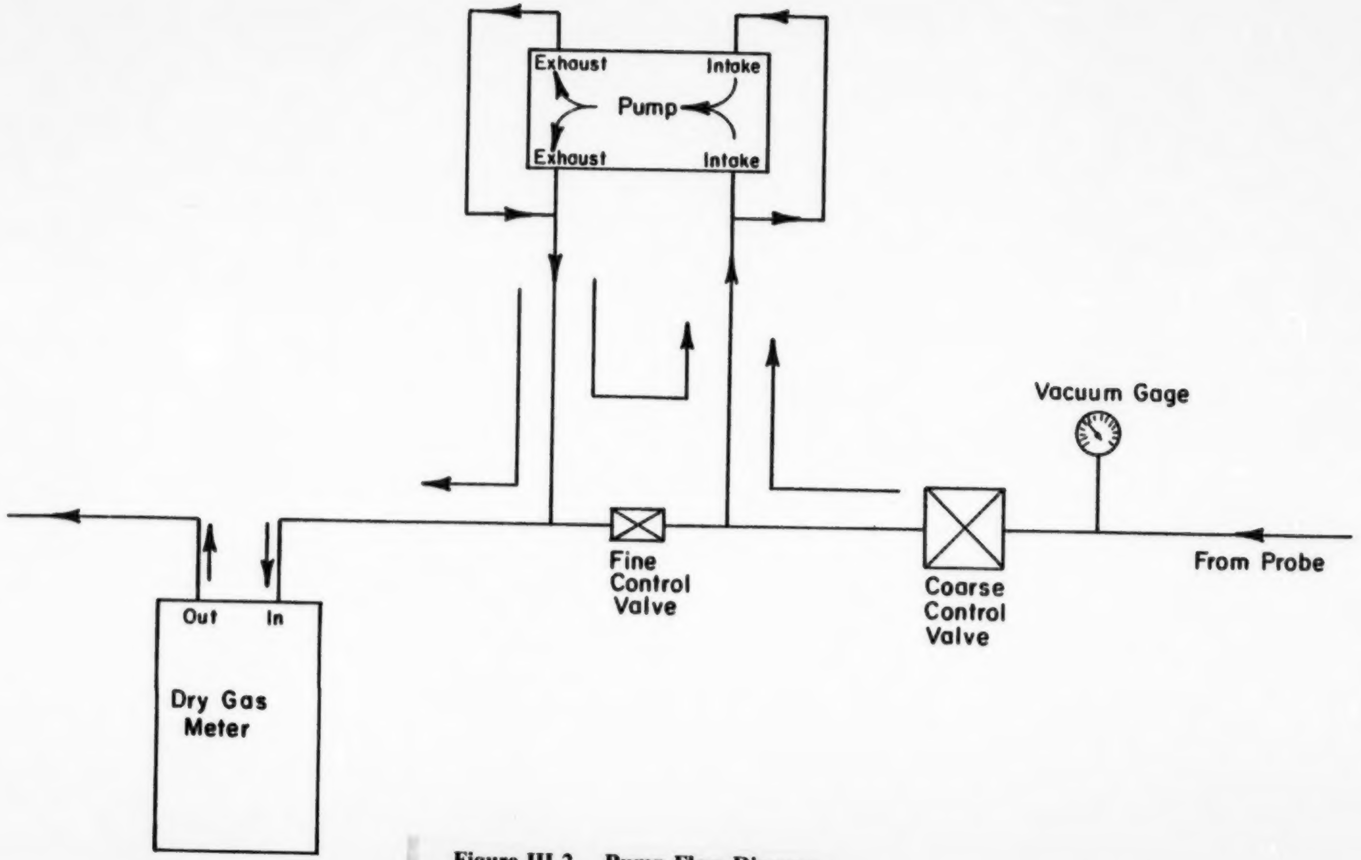
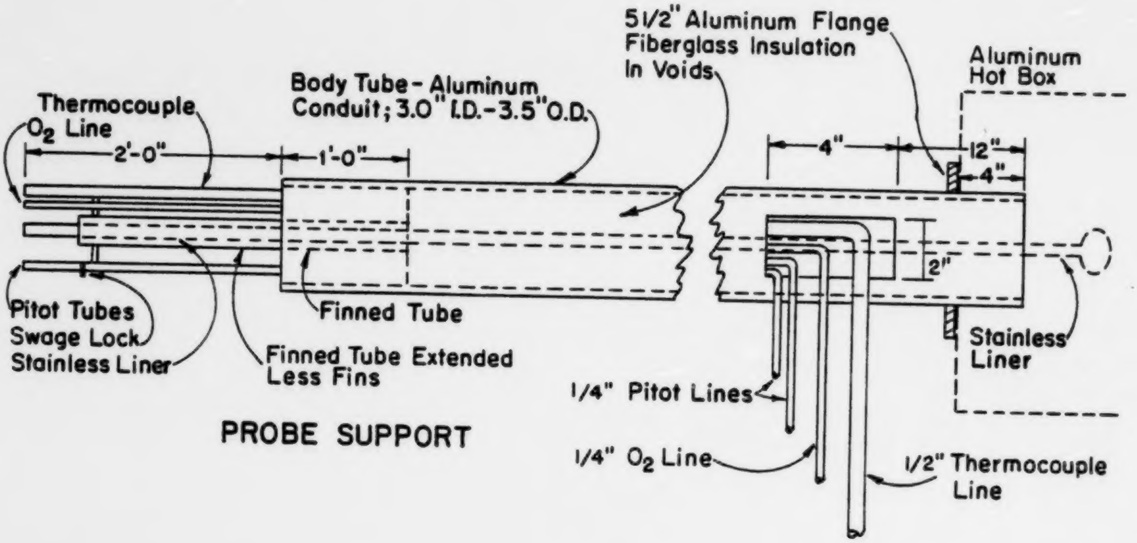
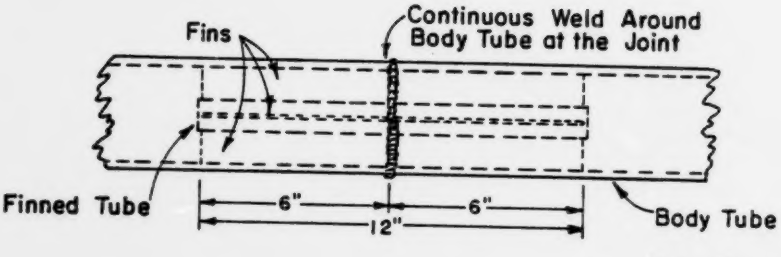

Exhaust
Intake
Pump
Exhaust
Intake
Vacuum Gage
From Probe
Coarse Control Valve
Fine Control Valve
Out
In
Dry Gas Meter

Figure III-2. Pump Flow Diagram.


5 1/2" Aluminum Flange
Fiberglass Insulation In Voids
Aluminum Hot Box
Body Tube - Aluminum Conduit; 3.0" I.D.-3.5" O.D.
Thermocouple
O$_2$ Line
2'-0"
1'-0"
4"
12"
4"
2"
Pitot Tubes
Swage Lock
Stainless Liner
Finned Tube
Finned Tube Extended Less Fins
Stainless Liner
1/4" Pitot Lines
1/4" O$_2$ Line
1/2" Thermocouple Line

PROBE SUPPORT

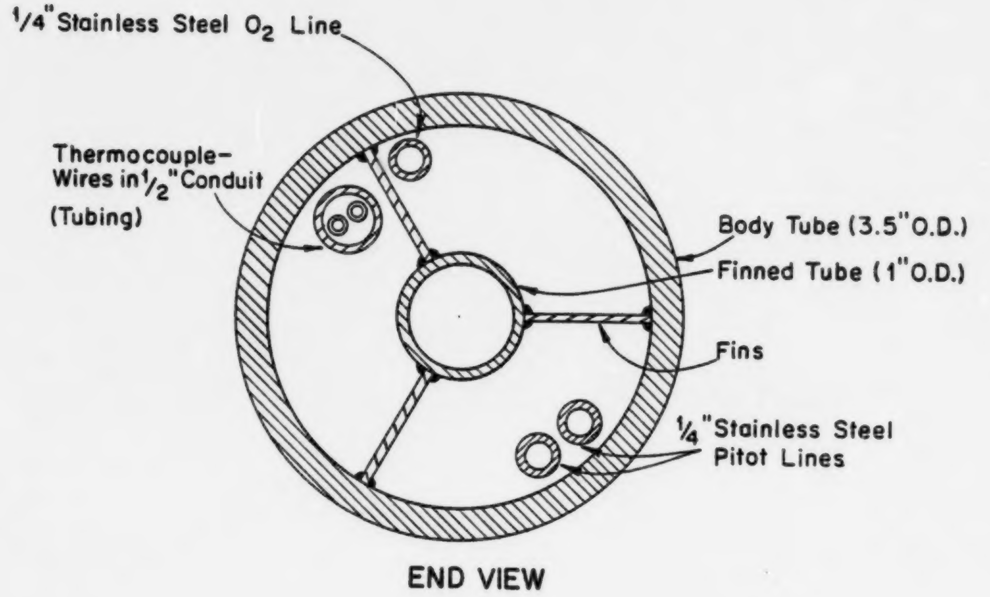
2 - 22 Foot Probes
2 - 32 Foot Probes


Fins
Continuous Weld Around Body Tube at the Joint
Finned Tube
6"
6"
12"
Body Tube

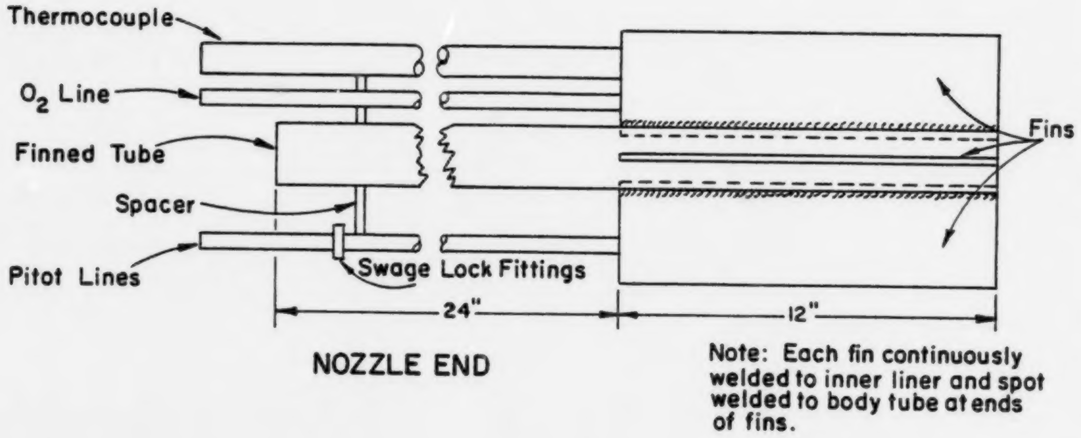
TYPICAL JOINT DETAIL

Note: Fins continuously welded to finned tube, spot welded to body tube at of fins.

Figure III-3. Manual Sampling Probes.



1/4" Stainless Steel O2 Line
Thermocouple-Wires in 1/2" Conduit (Tubing)
Body Tube (3.5" O.D.)
Finned Tube (1" O.D.)
Fins
1/4" Stainless Steel Pitot Lines
END VIEW



Thermocouple
O2 Line
Finned Tube
Spacer
Pitot Lines
Swage Lock Fittings
24"
12"
Fins
NOZZLE END
Note: Each fin continuously welded to inner liner and spot welded to body tube at ends of fins.

Figure III-4. Probe Liner Supports.

trically-insulated wire is spiraled the length of the probe, and two more layers of fiberglass tape are wrapped over that. On the stack probe, one 50-foot piece of nichrome wire is used. The two 22-foot probes have two 50-foot sections of nichrome wire hooked in parallel and the two 32-foot probes have two 25-foot sections and one 50-foot section of wire hooked in parallel. Figure III-5 shows the method of wrapping the nichrome wire. A 16 gauge, Teflon-insulated hook-up wire is attached to each probe liner to prevent electrical shock in case of a short. Pitot tube lines and thermocouple casing (copper tubing) are attached to the probes in the manner shown in Figure III-6.

3. Type S Pitot Tubes: The Type S pitot tubes are constructed of 1/4-inch OD stainless steel according to specifications in the August 4, 1978, Federal Register. They are approximately 18 inches long and have swage lock fittings for attachment to the pitot tube lines. A drawing of these tubes can be found in Figure III-7.

4. Umbilical Cord: Figure III-8 is an end view of the umbilical cord used on the stack. The pitot tube lines are 1/4-inch inside diameter (ID) welding tubing; the sampling hose is 1/4-inch ID, thick wall, Tygon tubing. They are taped together at approximately 1-foot intervals with black electrical tape. Pitot tube liners have 1/4-inch OD stainless steel tubing inserted in the end that goes to the sampling console and tygon tubing is attached to make connection to the console magnehelics easier. All tubing-to-hose connections are secured with hose clamps.

5. Probe Extensions: The extension of the probe from the hot box to the cold box for vertical sampling is a Teflon, high-temperature heated hose. The hose has a built-in electric heating element that can provide uniform heat up to 450°F throughout the entire length of the hose. The core is made of 1/2-inch ID Teflon and the hose has 1/2-inch of thermal insula-

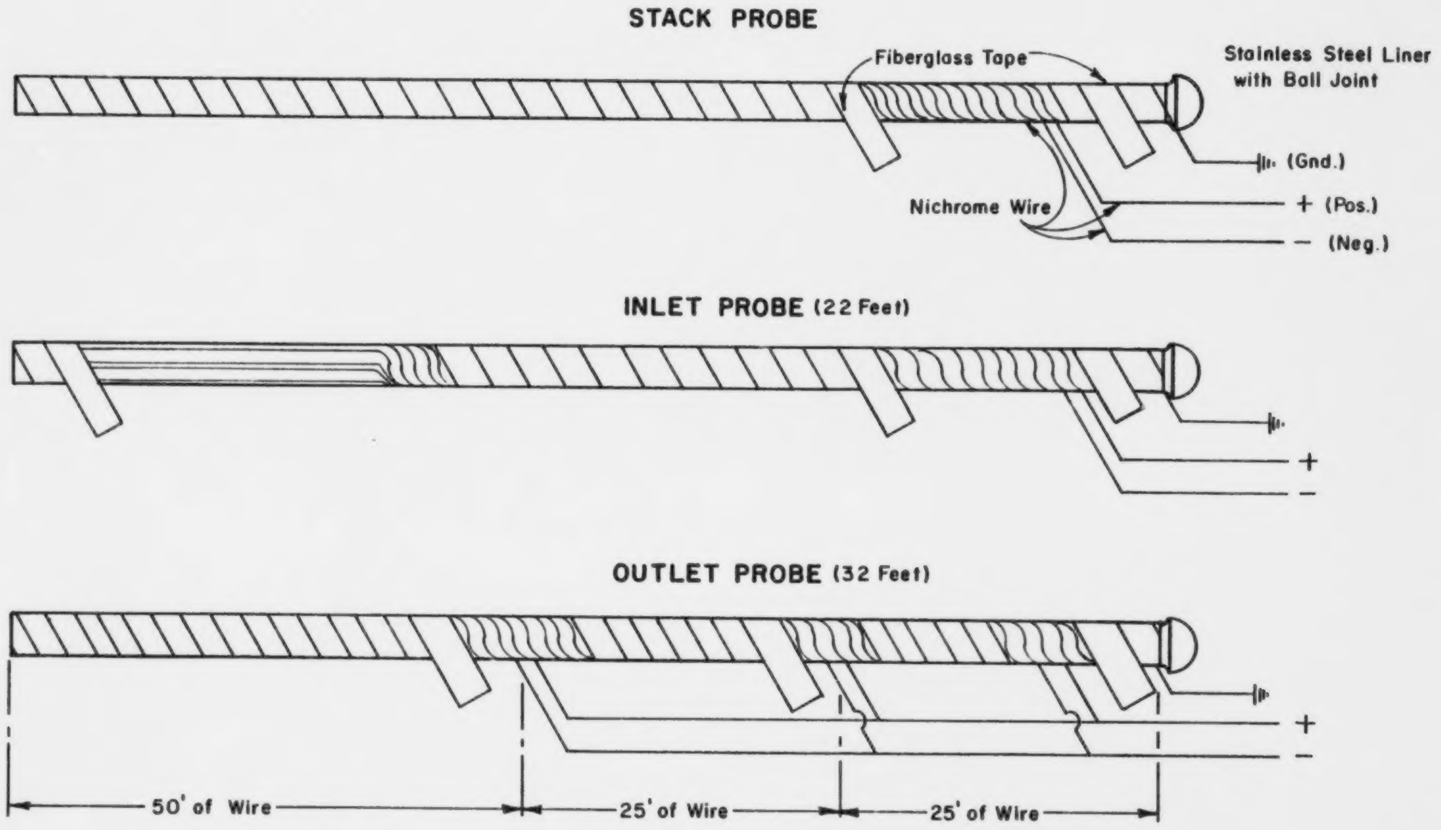

STACK PROBE
Fiberglass Tape
Stainless Steel Liner with Ball Joint
(Gnd.)
Nichrome Wire
+ (Pos.)
– (Neg.)
INLET PROBE (22 Feet)
+
–
OUTLET PROBE (32 Feet)
+
–
50' of Wire
25' of Wire
25' of Wire

Figure III-5. Method of Wrapping Nichrome Wire.

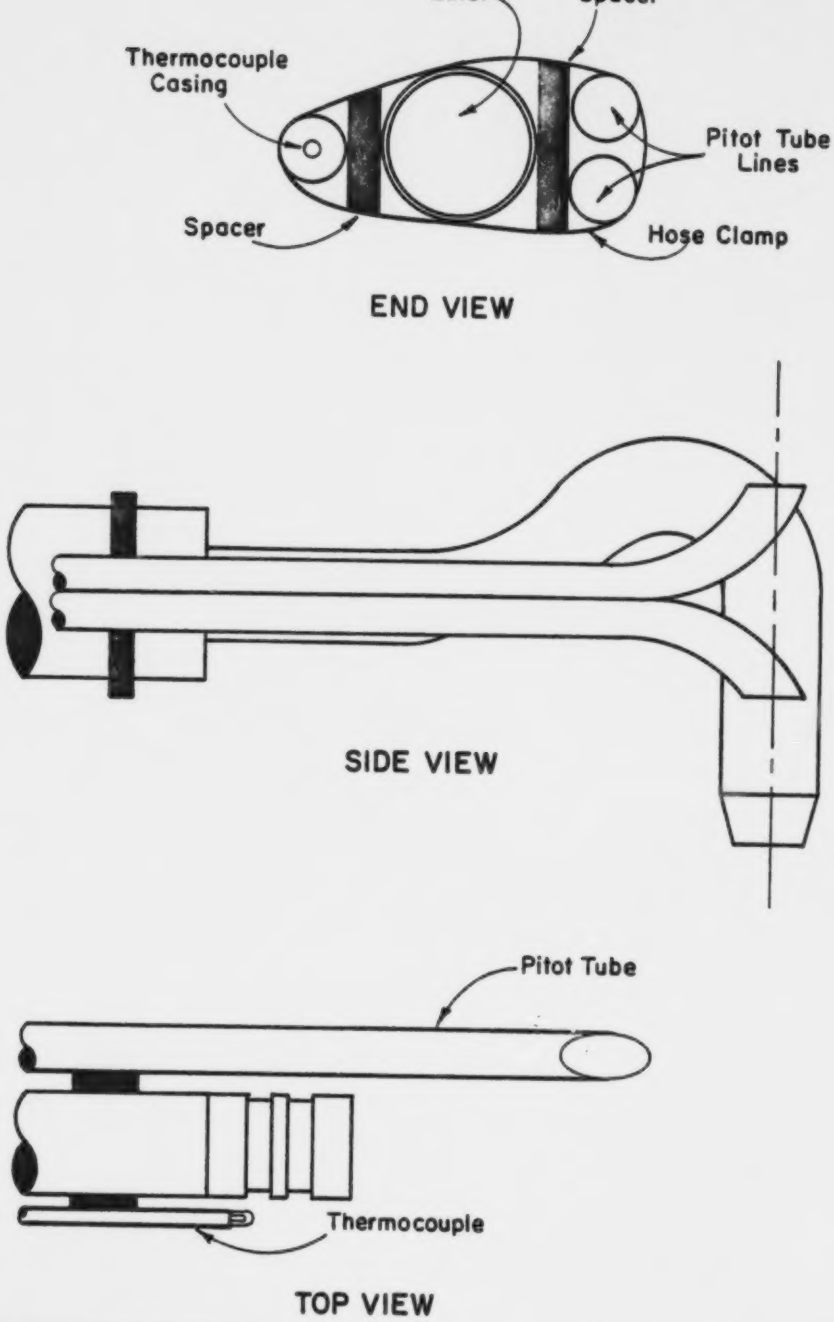
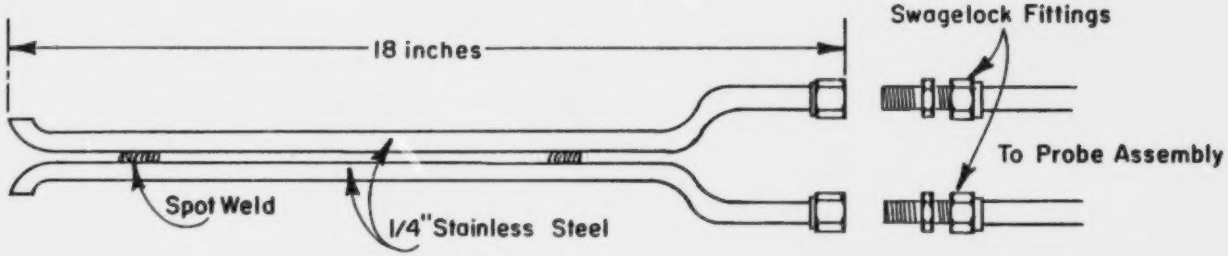

Liner
Spacer
Thermocouple Casing
Pitot Tube Lines
Spacer
Hose Clamp
END VIEW
SIDE VIEW
Pitot Tube
Thermocouple
TOP VIEW

Figure III-6. Attachment of Pitot Tube Lines and Thermocouple Casing.


18 inches
Swagelock Fittings
To Probe Assembly
Spot Weld
1/4"Stainless Steel

Note: Pitot tube lines and probe lines are color coded to maintain correct orientation – red and green.

Figure III-7. Type S Pitot Tubes.

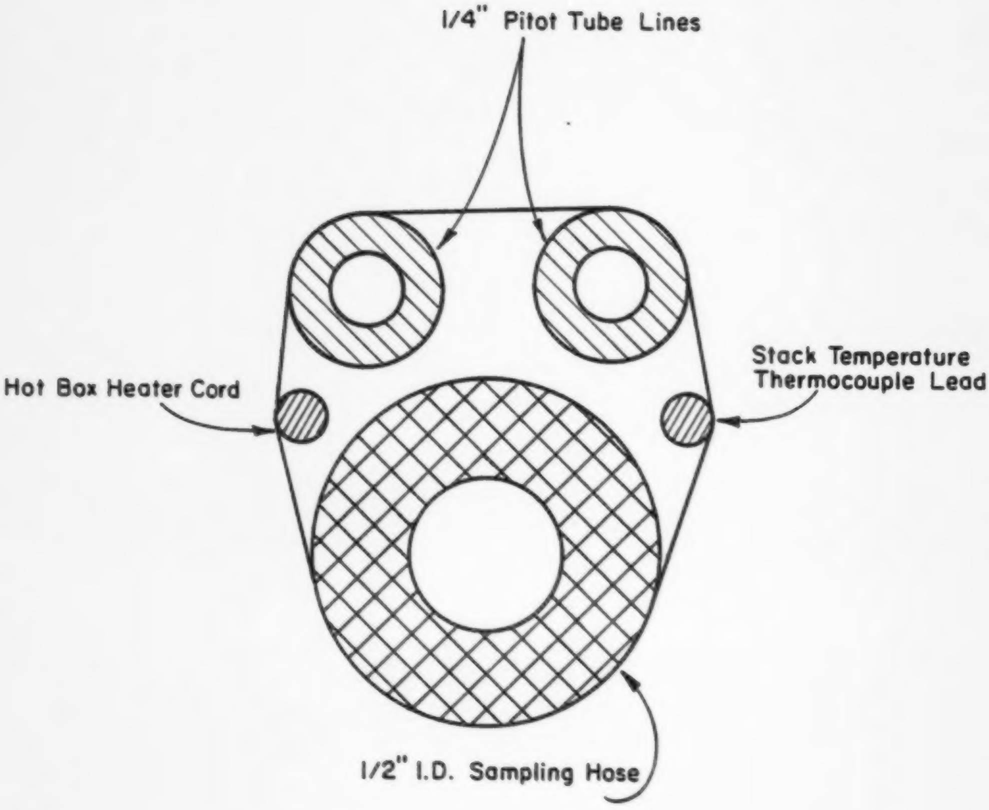

1/4" Pitot Tube Lines
Hot Box Heater Cord
Stack Temperature Thermocouple Lead
1/2" I.D. Sampling Hose

Figure III-8. Umbilical Cord.

tion. A drawing of this probe extension can be found in Figure III-9.

A drawing of a complete vertical sampling setup and a complete stack sampling setup can be seen in Figures III-10 and III-11.

During the week of December 11-15, 1978, Southwestern conducted tests for particulate, sulfur dioxide, and oxides of nitrogen at inlet, outlet, and stack locations for the Harrington Unit 2 baghouse. Sampling for mass emissions of these parameters was conducted according to EPA Methods 5, 6, and 7 as presented in 40 CFR 60, Appendix A. Results and discussion are as follows:

1. Particulate: Determinations of particulate concentrations were made at three locations (east inlet, west inlet and stack). Testing was not performed on each outlet because of two reasons. First, procurement problems with equipment did not allow for completion of the outlet sampling trains in time for the test period. Second, many of the testing personnel were inexperienced in stack sampling procedures. Because Southwestern was utilizing in-house personnel, it was believed that the test would result in better quality data if only three stations were sampled, allowing experienced personnel to work with the less experienced team members. During future tests, personnel at all five sampling locations will have some degree of experience.

During the first two runs for particulate collection, testing was conducted in conjunction with continuous soot blowing. This soot blowing appeared to significantly affect grain loading into the baghouse. The grain loading was approximately 30 percent higher during periods of sootblowing.

Particulate testing demonstrated that Unit 2 is operating within compliance of the existing New Source Performance Standard (NSPS) of .1 lb/10^6 Btu. However, the results are

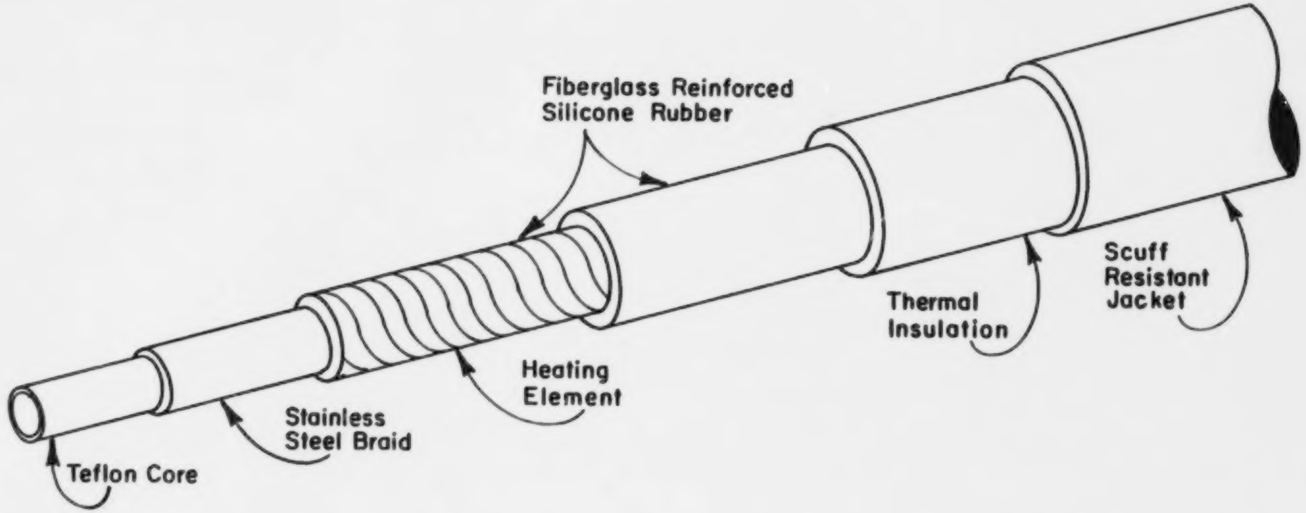

Fiberglass Reinforced Silicone Rubber
Scuff Resistant Jacket
Thermal Insulation
Heating Element
Stainless Steel Braid
Teflon Core

Figure III-9. Probe Extension.

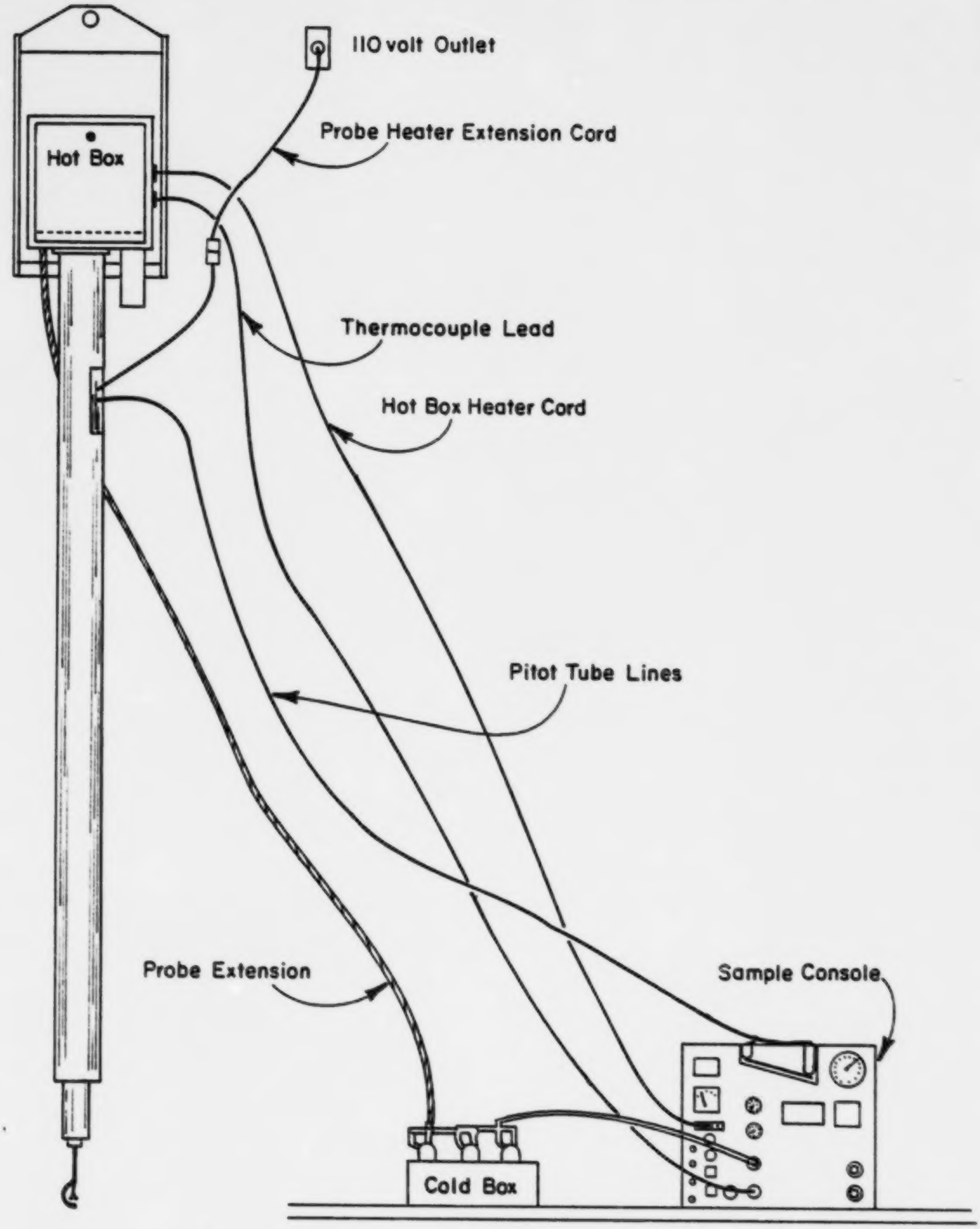

110 volt Outlet
Hot Box
Probe Heater Extension Cord
Thermocouple Lead
Hot Box Heater Cord
Pitot Tube Lines
Probe Extension
Sample Console
Cold Box

Figure III-10. Vertical Sampling Set-Up.

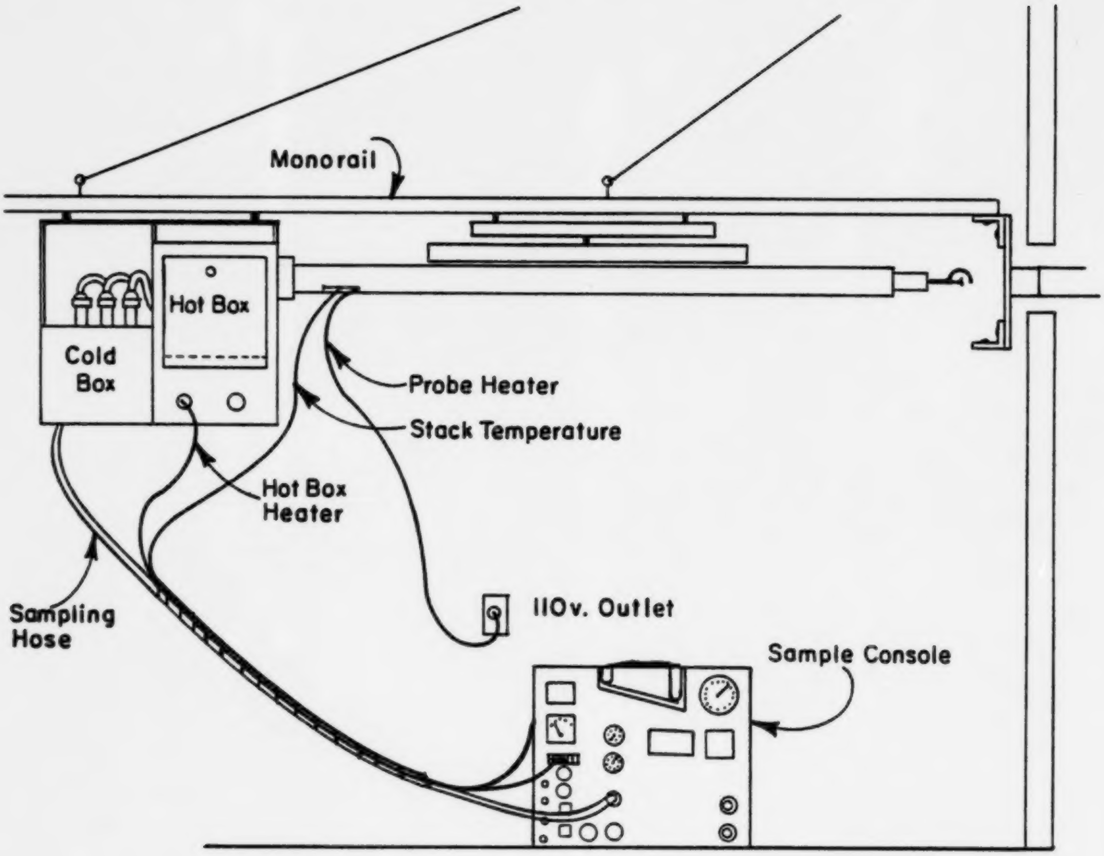

Monorail
Cold Box
Hot Box
Probe Heater
Stack Temperature
Hot Box Heater
Sampling Hose
110v. Outlet
Sample Console

Figure III-11. Stack Sampling Set-Up.

known to be biased (high) because of a probe heater failure that allowed moisture to condense in the probe and deposit in the cyclone ahead of the particulate filter.

The particulate data for each sampling location is presented in Tables III-2, III-3, and III-4.

2. Sulfur dioxide: Samples for sulfur dioxide were collected only at the two inlets and the stack for the same reasons as the particulate. The stack results are very comparable to the theoretical SO_2 concentrations. However, the high negative duct pressure of -16 inches H_2O caused problems in the sampling. The contents of the first impinger are normally thrown away and not analyzed. A portion of the absorbed SO_2 was thrown away, because the high negative pressure pulled the contents from the impingers forward into the first impinger. This problem seemed worse on the west inlet than on the east inlet as indicated in the sampling results. Prior to conducting the second set of tests a modification to the sample train will be employed to prevent the effect of the negative pressure from affecting the results. The results of the SO_2 testing are presented in Tables III-5, III-6 and III-7.

3. Nitrogen oxides: The sampling procedure for oxides of nitrogen requires less manpower and equipment than sampling for SO_2 and particulate; therefore, sampling for NO_x was performed at all five locations (two inlet, two outlet, one stack). Results indicated that the concentration of nitrogen oxides is consistent throughout the baghouse.

The only problem encountered was attributed to the cold December temperatures. These ambient temperatures caused problems in the initial operation of the vacuum pumps. External heat was applied to the pumps to promote initial operation. After the temperature rose in the pumps, no further problems were encountered. The results of the NO_x testing are presented in Tables III-8, III-9, III-10, III-11 and III-12.

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TABLE III-2. PARTICULATE TEST CALCULATIONS
WEST INLET

Run #	M_n mg	V_m cu ft	V_{mstd} cu ft	P_{bar} in Hg	ΔH in H_2O	T_m °R	B_{wo} Frac H_2o	V_s ft/sec	O_2	P_s in Hg	T_s °R	C_s lb/dscf $x10^{-4}$	C_s gr/scf
1*	12327.9	77.477	69.368	26.84	2.136	531.9	.121	61.93	5.8	25.66	800.2	3.9179	2.74
2.*	10371.3	80.550	70.980	26.43	2.251	532.4	.106	61.55	5.2	25.22	793.3	3.2213	2.26
3**	7573.4	83.504	71.594	26.20	2.346	542.6	.108	62.93	5.0	24.99	805.7	2.3321	1.63

Run #	Part. Emission Rate lb/hr	Gas Flow CFM	% Ash	Coal Flow Rate THP	BTU Value Coal Btu/lb	Heat Rate 10^6 Btu/hr	Load MW	% Opacity	% Isokinetic
1*	10,700	0	6.13	204.7	8525	3490.1	359.5	3.5	97.8
2*	8,800	0	5.62	205.8	8437	3472.7	359.2	2.8	97.7
3**	6,350	0	6.58	204.0	8517	3474.9	357.7	2.8	99.0

*Sootblowing continuously
**Not sootblowing

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TABLE III-3. PARTICULATE TEST CALCULATIONS
EAST INLET

Run #	M_n mg	V_m cu ft	V_{mstd} cu ft	P_{bar} in Hg	ΔH in H_2O	T_m °R	B_{wo} Frac H_2O	V_s ft/sec	O_2	P_s in Hg	T_s °R	C_s lb/dscf $x10^{-4}$	C_s gr/scf
1*	11625.9	85.961	76.78	26.84	1.998	532.96	.102	64.60	6.3	25.68	811.4	3.3381	2.34
2*	10523.7	90.825	79.524	26.43	2.11	535.6	.114	64.11	6.1	25.31	805.4	2.9174	2.04
3**	7836.6	84.307	72.425	26.20	2.19	541.3	.116	66.07	5.3	25.02	821.8	2.3854	1.67

Run #	Part. Emission Rate lb/hr	Gas Flow CFM	% Ash	Coal Flow Rate THP	BTU Value Coal Btu/lb	Heat Rate 10^6 Btu/hr	Load MW	% Opacity	% Isokinetic
1*	9,500	0	6.13	204.7	8525	3490.1	359.5	3.5	105.6
2*	8,140	0	5.62	205.8	8437	3472.7	359.2	2.8	112.5
3**	6,830	0	6.58	204.0	8517	3474.9	357.7	2.8	102.8

*Sootblowing continuously
**Not sootblowing

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TABLE III-4. PARTICULATE TEST CALCULATIONS
STACK EPA METHOD

RUN #	M_n mg	V_m cu ft	V_{mstd} cu ft	P_{bar} in Hg	$\triangle H$ in H_2o	T_m °R	B_{wo} Frac H_2O	V_s ft/sec	O_2 %	P_s in Hg	T_s °R	C_s lb/dscf	C_s gr/scf
1	126.7	39.574	36.58	26.70	.45	510.1	.089	82.91	6.2	26.64	815.2	7.6348×10^{-6}	.053
2	119.0	40.224	36.42	26.29	.45	512.8	.092	82.34	5.8	26.22	810.3	7.2028×10^{-6}	.050
3	76.4	40.187	35.97	26.06	.46	515.7	.096	84.37	5.4	26.00	820.3	4.6825×10^{-6}	.033

Run #	F Factor	Part. Emission Rate lb/hr	Total Gas Flow Rate CFM	Coal Flow Rate TPH	Btu Value Coal Btu/lb	Heat Rate 10^6 Btu/hr	Load MW	% Opacity	% Isokinetic	Particulate Emission Rate lb/10^6 Btu
1	9758	370	0	204.7	8525	3490.1	359.5	3.5	97.7	.106
2	9779	337	0	205.8	8437	3472.7	359.2	2.8	99.3	.097
3	9728	212	0	204.0	8517	3474.9	357.7	2.8	97.7	.061

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TABLE III-5. SO_2 CALCULATIONS (West Inlet)

V_{tb} = 0 ml N = .0098 gm-eq/l V_{soln} = 500 ml V_a = 20 ml

Sample	Port	C_{SO_2} Tb/dscf x10^{-5}	V_t ml	V_{mstd} cu ft	V_m cu ft	T_m °R	P_{bar} in Hg	F_{calc} dscf/10^6 Btu	O_2 %	Lb/10^6 Btu Method 6	Lb/10^6 Btu Analyzer
1	6	3.3772	4.25	2.177	2.430	522.6	26.54	9739	5.2	.44	.54
2	5	2.0843	1.83	1.519	1.745	537.5	26.53	9739	5.2	.27	.56
3	4	2.1107	2.20	1.803	2.092	542.1	26.49	9739	5.1	.27	.58
4	3	2.8262	3.00	1.836	2.161	549.6	26.48	9739	5.1	.36	.58
5	2	2.1282	2.05	1.666	1.956	547.9	26.46	9739	5.5	.28	.59
6	1	.8388	.35	.722	.841	544.2	26.47	9739	5.5	.11	.60

Note 1: The measurements of SO_2 are obviously low. It appears the vacuum from the duct has drawn the absorbing solution from impingers #2 and #3 into the throw-away impinger #1. An investigation is underway to determine a method to prevent this from recurring.

Note 2: The reference Method 6 concentrations were determined for a twenty minute period. The analyzer concentration was determined for a 60 minute period. The analyzer concentration is determined by using the 0_2 concentration from the 0_2 analyzer rather than the Orsat.

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TABLE III-6. SO_2CALCULATIONS (East Inlet)

V_{tb} = 0 ml

N = .0098 gm-eq/l

V_{soln} = 500 ml

V_a = 20 ml

Sample	Port	C_{SO_2} Tb/dscf $x10^{-6}$	V_t ml	V_{mstd} cu ft	V_m cu ft	T_m °R	P_{bar} in Hg	F_{calc} dscf/10^6 Btu	O_2 %	Lb/10^6 Btu Method 6	Lb/10^6 Btu Analyzer
1	7	3.8198	5.28	2.391	2.736	535.7	26.54	9739	6.7	.55	.57
2	6	3.5218	4.38	2.151	2.478	539.1	26.53	9739	6.7	.51	.55
3	5	3.5304	4.18	2.048	2.387	544.6	26.49	9739	7.0	.52	.55
4	3	4.4920	5.35	2.060	2.413	547.1	26.48	9739	7.0	.66	.57
5	2	4.5805	5.13	1.937	2.289	551.4	26.46	9739	6.5	.65	.57
6	1	4.1757	4.53	1.877	2.217	551.5	26.47	9739	6.5	.59	.59

Note 1: The measurements of SO_2 are suspected of being low. It appears the vacuum in the duct has drawn the absorbing solution from impingers #2 and #3 into the throw-away impinger #1. An investigation is underway to determine a method to prevent this from recurring.

Note 2: The reference Method 6 concentrations were determined for a twenty minute period. The analyzer concentration was determined for a sixty minute period. The analyzer concentration was determined by using the 0_2 concentration from the 0_2 analyzer rather than the Orsat.

TABLE III-7. SO_2 CALCULATIONS (Stack)

V_{tb} = 0 ml N = .0098 gm-eq/l V_{soln} = 500 ml V_a = 20 ml

Sample	Port	C_{SO_2} Tb/dscf x10^{-5}	V_t ml	V_{mstd} cu ft	V_m cu ft	T_m °R	P_{bar} in Hg	F_{calc} dscf/10^6 Btu	O_2 %	Lb/10^6 Btu Method 6	Lb/10^6 Btu Analyzer
1	1	5.1583	9.85	3.303	3.683	519.2	26.40	9739	6.2	.71	.62
2	2	5.3598	5.575	1.799	2.020	522.6	26.39	9739	6.2	.74	.62
3	3	5.3800	5.475	1.761	1.995	526.7	26.35	9739	6.5	.76	.62
4	4	5.5613	6.825	2.123	2.419	529.5	26.34	9739	6.5	.79	.63
5	1	6.0555	6.875	1.964	2.240	529.6	26.32	9739	6.3	.84	.64
6	2	6.0410	6.60	1.890	2.152	528.8	26.33	9739	6.3	.84	.67

Note: The reference Method 6 concentration was determined for a twenty minute period. The analyzer concentration was determined for a 60 minute period. The analyzer concentration was determined by using the 0_2 concentration from the 0_2 analyzer rather than the Orsat.

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TABLE III-8. NO$_X$ TEST CALCULATIONS
FUEL: 100% COAL

WEST INLET

Run #	Test	V_f ml	P_i in Hg	T_i °R	P_f in Hg	T_f °R	m Mg	V_{sc} ml	C x 10^{-5} lb/dscf	F_{calc} dscf/10^6 Btu	O_2 %	Lb/10^6 Btu Method 7
1	A	2053	1.03	513	26.44	534	1270	1699.45	4.6654	9757	5.5	.62
1	B	2076	.23	512	26.24	534	Invalid------	------------	----Sample	9757	5.5	—
1	C	2064	1.13	513	26.84	534	Invalid------	------------	----Sample	9757	5.5	—
1	D	2059	1.03	516	26.09	533	1205	1684.67	4.4655	9557	5.5	.59
2	A	2050	.93	514	25.79	536	1145	1654.11	4.3215	9757	5.3	.56
2	B	2064	.73	514	26.14	537	1270	1699.76	4.6645	9757	5.3	.61
2	C	2053	.53	518	25.44	537	1245	1658.16	4.6874	9757	5.3	.61
2	D	2066	.63	515	25.84	537	1245	1688.4	4.6035	9757	5.3	.60
3	A	2075	.73	512	18.04	536	730	1165.54	3.9101	9757	5.7	.52
3	B	2102	.63	510	26.24	535	1255	1751.73	4.4727	9757	5.7	.60
3	C	2091	.83	510	26.04	537	1450	1707.93	5.3002	9757	5.7	.71
3	D	2072	.73	509	26.24	536	1350	1715.94	4.9116	9757	5.7	.66

According to 40 CFR 60, 46 (e) each run shall consist of at least four grab samples taken at approximately 15 minute intervals. The arithmetic mean of the samples shall constitute the run value.

$$\text{Run 1: } \frac{.62 + .59}{2} \text{ lb/10}^6 \text{ Btu} = \underline{\ .61\ } \text{ lb/10}^6 \text{ Btu}$$

$$\text{Run 2: } \frac{.56 + .61 + .61 + .60}{4} \text{ lb/10}^6 \text{ Btu} = \underline{\ .59\ } \text{ lb/10}^6 \text{ Btu}$$

$$\text{Run 3: } \frac{.52 + .60 + .71 + .66}{4} \text{ lb/10}^6 \text{ Btu} = \underline{\ .62\ } \text{ lb/10}^6 \text{ Btu}$$

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TABLE III-9. NO_x TEST CALCULATIONS
FUEL: 100% COAL

EAST INLET

Run #	Test	V_f ml	P_i in Hg	T_i °R	P_f in Hg	T_f °R	m Mg	V_{sc} ml	C x 10^{-5} lb/dscf	F_{calc} dscf/10^6 Btu	O_2 %	Lb/10^6 Btu Method 7
1	A	2036	2.43	520	25.79	537	1170	1537.91	4.7495	9757	7.2	.71
1	B	2023	1.63	520	26.29	531	Invalid	------------------	Sample	9757	7.2	—
1	C	2070	1.63	520	26.44	534	1145	1673.05	4.2726	9757	7.2	.64
1	D	2070	1.83	520	26.29	533	Invalid	------------------	Sample	9757	7.2	—
2	A	2052	1.43	518	26.44	533	1145	1675.02	4.2676	9757	7.9	.67
2	B	2061	1.53	515	26.44	535	1160	1668.24	4.3410	9757	7.9	.68
2	C	2056	1.53	515	26.44	535	1270	1664.15	4.7644	9757	7.9	.75
2	D	2049	1.33	516	26.44	537	1270	1665.88	4.7594	9757	7.9	.75
3	A	2059	1.43	515	26.44	536	1170	1670.26	4.3732	9757	7.0	.64
3	B	2052	1.33	516	26.44	534	1205	1678.24	4.4826	9757	7.0	.66
3	C	2041	1.53	513	26.54	535	1270	1658.09	4.7818	9757	7.0	.70
3	D	2073	1.43	520	26.24	532	1245	1682.54	4.6195	9757	7.0	.68

According to 40 CFR 60, 46 (e) each run shall consist of at least four grab samples taken at approximately 15 minute intervals. The arithmetic mean of the samples shall constitute the run value.

$$\text{Run 1: } \frac{.71 + .64}{2} \text{ lb}/10^6 \text{ Btu} = \underline{\ .68\ } \text{ lb}/10^6 \text{ Btu}$$

$$\text{Run 2: } \frac{.67 + .68 + .75 + .75}{4} \text{ lb}/10^6 \text{ Btu} = \underline{\ .71\ } \text{ lb}/10^6 \text{ Btu}$$

$$\text{Run 3: } \frac{.64 + .66 + .70 + .68}{4} \text{ lb}/10^6 \text{ Btu} = \underline{\ .67\ } \text{ lb}/10^6 \text{ Btu}$$

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TABLE III-10. NO_x TEST CALCULATIONS
FUEL: 100% COAL

WEST OUTLET

Run #	Test	V_f ml	P_i in Hg	T_i °R	P_f in Hg	T_f °R	m Mg	V_{sc} ml	C x 10^{-6} lb/dscf	F_{calc} dscf/10^6 Btu	O_2 %	Lb/10^6 Btu Method 7
1	A	2017	1.83	515	25.49	535	1120	1549.32	4.5130	9757	5.9	.61
1	B	2067	.83	515	25.54	535	Invalid	----------------	Sample	9757	5.9	.64
1	C	2054	1.63	516	25.69	536	1160	1602.39	4.5194	9757	5.9	.61
1	D	2084	1.63	515	25.54	534	1189	1622.18	4.5797	9757	5.9	.62
2	A	2068	1.63	523	25.69	536	1145	1614.98	4.4262	9757	5.9	.60
2	B	2048	1.43	518	25.64	535	220	Invalid------	Sample	9757	5.9	—
2	C	2085	1.63	516	25.54	535	1130	1619.94	4.3548	9757	5.9	.59
2	D	2104	1.63	515	25.54	533	1270	1641.23	4.8309	9757	5.9	.66
3	A	2026	1.63	512	25.74	537	1110	1579.55	4.3872	9757	5.1	.57
3	B	2050	1.63	515	25.54	535	1230	1592.20	4.8228	9757	5.1	.62
3	C	2074	1.63	510	25.84	538	1330	1620.48	5.1239	9757	5.1	.66
3	D	2079	1.63	514	25.74	535	1230	1628.33	4.7158	9757	5.1	.61

According to 40 CFR 60, 46 (e) each run shall consist of at least four grab samples taken at approximately 15 minute intervals. The arithmetic mean of the samples shall constitute the run value.

Run 1: $\frac{.61 + .64 + .61 + .62}{4}$ lb/10^6 Btu = $\underline{.62}$ lb/10^6 Btu

Run 2: $\frac{.60 + .59 + .66}{3}$ lb/10^6 Btu = $\underline{.62}$ lb/10^6 Btu

Run 3: $\frac{.57 + .62 + .66 + .61}{4}$ lb/10^6 Btu = $\underline{.62}$ lb/10^6 Btu

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TABLE III-11. NO_x TEST CALCULATIONS
FUEL: 100% COAL

EAST OUTLET

Run #	Test	V_f ml	P_i in Hg	T_i °R	P_f in Hg	T_f °R	m Mg	V_{sc} ml	C x 10^{-6} lb/dscf	F_{calc} dscf/10^6 Btu	O_2 %	Lb/10^6 Btu Method 7
1	A	1996	2.23	509	26.14	534	1070	1549.64	4.3107	9757	7.3	.65
1	B	2081	1.93	516	25.34	537	1145	1575.76	4.5364	9757	7.3	.68
1	C	2041	1.43	515	25.69	536	1060	1605.72	4.1213	9757	7.3	.62
1	D	2081	2.03	514	26.24	534	1060	1638.91	4.0378	9757	7.3	.61
2	A	2034	2.53	515	25.84	533	1030	1543.98	4.1647	9757	7.6	.64
2	B	2051	1.83	513	25.84	539	1145	1585.84	4.5075	9757	7.6	.69
2	C	2086	1.93	515	26.14	534	1205	1643.43	4.5775	9757	7.6	.70
2	D	2074	2.23	512	26.29	535	1145	1618.71	4.4160	9757	7.6	.68
3	A	2058	2.43	513	26.24	535	1070	1589.05	4.2038	9757	7.7	.65
3	B	2058	2.03	512	25.64	535	Invalid	----------------	Sample	9757	7.7	—
3	C	2068	2.43	516	26.19	532	1205	1604.44	4.6888	9757	7.7	.72
3	D	2068	2.23	512	26.14	533	1270	1610.48	4.9231	9757	7.7	.76

According to 40 CFR 60, 46 (e) each run shall consist of at least four grab samples taken at approximately 15 minute intervals. The arithmetic mean of the samples shall constitute the run value.

Run 1: $\frac{.65 + .68 + .62 + .61}{4}$ lb/10^6 Btu = .64 lb/10^6 Btu

Run 2: $\frac{.64 + .69 + .70 + .68}{4}$ lb/10^6 Btu = .68 lb/10^6 Btu

Run 3: $\frac{.65 + .72 + .76}{3}$ lb/10^6 Btu = .71 lb/10^6 Btu

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TABLE III-12. NO_X TEST CALCULATIONS
FUEL: 100% COAL

STACK												
Run #	Test	V_f ml	P_i in Hg	T_i °R	P_f in Hg	T_f °R	m Mg	V_{sc} ml	C lb/dscf	F_{calc} dscf/10^6 Btu	O_2 %	Lb/10^6 Btu Method 7
1	A	2027	1.89	504	28.19	535	1255	1728.39	4.5331	9757	6.5	.64
1	B	2035	1.89	509	27.54	535	1270	1693.52	4.6817	9757	6.5	.66
1	C	2041	1.99	515	27.89	536	1230	1713.02	4.4827	9757	6.5	.63
1	D	2040	2.09	513	27.59	536	1145	1684.81	4.2428	9757	6.5	.60
2	A	2047	1.49	516	27.59	533	1205	1743.31	4.3152	9757	7.2	.64
2	B	2017	1.59	515	27.74	534	1205	1716.89	4.3816	9757	7.2	.65
2	C	2043	1.54	506	27.69	533	1270	1740.99	4.5541	9757	7.2	.68
2	D	2035	1.49	506	27.54	537	1245	1713.97	4.5348	9757	7.2	.67
3	A	2043	1.49	504	26.94	537	1270	1680.60	4.7177	9757	6.0	.65
3	B	2034	.99	505	27.69	536	1255	1761.31	4.4484	9757	6.0	.61
3	C	2046	1.59	505	27.64	536	1320	1726.15	4.7708	9757	6.0	.65
3	D	2041	1.69	509	27.64	533	1320	1726.09	4.7742	9757	6.0	.65

According to 40 CFR 60, 46 (e) each run shall consist of at least four grab samples taken at approximately 15 minute intervals. The arithmetic mean of the samples shall constitute the run value.

Run 1: $\frac{.64 + .66 + .63 + .60}{4}$ lb/10^6 Btu = $\underline{\quad .63 \quad}$ lb/10^6 Btu

Run 2: $\frac{.64 + .65 + .68 + .67}{4}$ lb/10^6 Btu = $\underline{\quad .66 \quad}$ lb/10^6 Btu

Run 3: $\frac{.65 + .61 + .65 + 65}{4}$ lb/10^6 Btu = $\underline{\quad .64 \quad}$ lb/10^6 Btu

The final results of the particulate, sulfur dioxide and oxides of nitrogen are presented in Table III-13. Raw field data is presented in Appendix A. The results of the inlet testing compare favorably with the theoretical inlet grain loading. The theoretical inlet grain loading is estimated and based upon generation of 80% fly ash. The percent fly ash has never been accurately determined but has been estimated to be between 70 percent and 80 percent. The stack grain loading is suspected of being high by at least a factor of 2, because of the use of the unheated probe. The stack concentration should be accurately determined during the next set of tests.

Results of the NO_x testing tend to be very consistent across the baghouse. The results of the sulfur dioxide tests on the stack compare favorably with the stoichiometric calculation for sulfur dioxide. The reason for the erratic inlet results has been determined and will be corrected before the second set of tests.

A number of problems were encountered during the first special testing of the FFS by Southwestern test crews. The problems and corrective measures taken are described below:

1. The first problem encountered during the special testing involved the NO_x sampling train. The extreme cold temperatures apparently caused the oil in the pump to thicken, which caused the electrical motor to overheat and shut off. For future tests, pumps will be operated indoors just before taking them to the sample station and letting them continue to operate with valves open prior to evacuating the NO_x flasks.

2. During the SO_2 sampling it was determined that high vacuum was required for each of the SO_2 sampling stations. This problem was also experienced on the stack. An investigation of all impingers revealed none were plugged. The run proceeded with about 10 inches Hg required to pull the sample. This problem did not occur during the remainder of the runs and no explanation could account for the high vacuum. A

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TABLE III-13. RESULTS OF PARTICULATE TESTING

Run #	East Inlet gr/SCF	West Inlet gr/SCF	Theoretical Inlet + gr/SCF	Stack*** gr/SCF	Stack*** lb/10^6 Btu
1*	2.28	2.74	2.09	.053	.106
2*	2.04	2.26	1.96	.050	.097
3**	1.67	1.63	2.27	.033	.061

*sootblowing continuously

**not sootblowing

***The concentrations of particulate obtained from the stack are biased high because of a reaction took place in the unheated Inconel probe liner.

+ assumes 70% Fly ash, 30% bottom ash and economizer ash; no consideration for sootblowing.

RESULTS OF NO$_x$ TESTING

Run #	East Inlet Method 7	East Outlet Method 7	West Inlet Method 7	West Outlet Method 7	Stack Method 7
1	.68	.64	.61	.62	.63
2	.71	.68	.59	.62	.66
3	.67	.71	.62	.62	.64

RESULTS OF SO$_2$TESTING

Run #	East Inlet* Method 6 lb/10^6 Btu	West Inlet* Method 6 lb/10^6 Btu	Stoichiometric** lb/10^6 Btu	Stack Method 6 lb/10^6 Btu
1	.53	.36	.76	.73
2	.59	.32	.84	.78
3	.62	.20	.88	.84

*These concentrations are suspected of being low because of the high negative pressure pulling the absorbing solutions forward, thereby resulting in the absorbed SO$_2$ not being analyzed.

**assumes all sulfur is converted to SO$_2$.

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special effort was made during remaining runs to avoid putting too much glass wool in the first impinger.

3. This problem actually resulted after the test, and is reflected in the SO_2 results. The concentration of SO_2 in each of the inlet ducts appeared to be low; in addition, results were erratic on the west inlet. The only explanation for these results is that the high vacuum on the inlet duct actually pulled the reagent on impinger #2 and #3 forward into impinger #1. The first impinger was routinely thrown away and was not included in the analysis.

As a result, part of the absorbed SO_2 may have been thrown away. To prevent this from happening again, a check valve will be installed behind the last impinger. The check valve should be used prior to the next test and in the event the check valve does not solve the problem, another valve should be installed ahead of the first impinger. (Both of these valves were used by GCA on their sampling train.)

4. During Run #1 for particulate, the stack location experienced a rheostat failure for the hot box. The problem was resolved by wiring around the rheostat in the control console. This direct wiring to the hot box did not present a problem because of the cold ambient temperatures. Before the next test all rheostats should be checked out and changed if repair is needed.

5. During particulate sample collection at the stack location, the Inconel probe liner developed problems with the heating element and resulted in the probe being operated without heat. It was noted that a green liquid was forming in the cyclone. During probe wash and sample recovery this green solution was kept separate from the rest of the samples. This solution was evaporated and used to determine the total weight gain of the particulate catch. The collected solution resulted in a higher than expected weight gain. The material was later redissolved and analyzed for nickel. Nickel appeared to

be approximately 17 percent of the total cyclone catch. It is believed that a nickel/sulfur based compound was forming in the unheated Inconel probe. In the future no testing will be performed with an unheated probe liner.

6. During Run #1 for particulate (on the west and east inlets), the vacuum became high about midway through the run, making it impossible to maintain the required ΔH for isokinetic sampling rate. The filter was replaced in the hot box because filter plugging was suspected; this did not solve the problem. Further investigation revealed the impinger tip was plugged with silica gel. The silica gel was removed and flow returned to normal. Glass wool was placed in the impinger tip and no other problems were encountered.

The high pressure drop pulled the filter up from its holding plate, during several of the runs on the inlet. This allowed particulate to go past the filter and into the impingers. The first three impingers in each train were analyzed for particulate weight gain, because of this problem. This resulted in the analysis requiring a much longer period of time, but allowed the recovery of all the samples.

7. The same problem as described in Item 6 also occurred on the west and east inlets. The filter apparently was pulled off the fritted disc in the filter holder because of the high vacuum in the inlet ducts. The filter holder was tightened further on Run #3. This solved the problem for the east inlet, but the west inlet filter was still pulled out on Run #2. As a result of these filter failures, ash escaped into the cold box impinger. These impinger catches were evaporated and included in the mass emission rates. In addition, the gasket was placed on top of the filter, which resolved the tearing of the filter.

8. Blanks on some of the data collection forms were not completely filled out. On future tests extra care should be taken by the console operator to complete the necessary blanks.

9. During some of the particulate runs the fritted discs broke and caused the filter to tear up. An attempt should be made to support this filter before the next special test is performed.

10. Since the NO_x concentration was consistent at all locations, it was decided to eliminate future testing for NO_x. (This was confirmed by GCA testing.) The discontinuance of NO_x testing will help in minimizing the cost of the test program.

B. First GCA Test

In September of 1978, Southwestern selected GCA Corporation of Bedford, Massachusetts to perform special tests and analysis as specified in the Project Scope of Work. The first GCA special test was completed during the last week of February, 1979. GCA brought 17 people to the Harrington Station site to conduct the test program. All collected samples were secured and shipped to GCA's laboratory in Massachusetts via their truck.

The GCA test was designed to determine particulate mass collection efficiency, the level of sulfur and nitrogen oxides, concentration and emission rates, the concentration of organic material in the flue gas, and elemental and inorganic compound analysis of the collected fly ash. A summary of the GCA test program is given in Table III-14. Sampling was carried out in the east and west duct preceding the baghouse, in the east and west ducts after the baghouse, and in the stack after the I.D. fans (see Figure III-12).

Results of the GCA special test for particulate, SO_2 and NO_x are presented in Table III-15. Mass emissions of particulate were conducted at the stack location with five sampling runs. Mass emissions ranged from .007 $lbs/10^6$ Btu to .034 $lbs/10^6$ Btu. Average particulate collection efficiency was determined to be 99.3%. SO_2 emissions were within New Source

TABLE III.-14. SUMMARY OF GCA SAMPLING PROGRAM

Pollutant sampled	Number of measurements made per sampling location	Number of samples per measurement	Duration of sample collection	Number of sample points per measurement
Particulate C_7-C_{16} and $>C_{17}$ Organic compounds	6 3	1 1	245 minutes inlet and outlet ducts 240 minutes stack	49 24
CO_2, CO and O_2 C_1-C_6 Organic compounds	6 3	1 1	245 minutes inlet and outlet ducts 240 minutes stack	49 24
SO_2 Method 6	3	2	30 minutes	1
SO_3 and SO_2 Method 8	3	1	245 minutes inlet and outlet 240 minutes stack	49 24
NO_x	3	4	1 sample every 15 minutes for 15 seconds	1
Particle Size Impactors	3	1	~5 minutes inlet, 700 minutes outlet and stack	1 min. 2
Particle Size DD and CNC	1	min. 3 max. 5	Variable	1
Particle Size EOC	1	6 outlet 7 inlet	Variable	1

TABLE III-15. GCA DATA SUMMARY

Results Of Particulate Testing EPA Method 5

Run #	East Inlet gr/SCF	West Inlet gr/SCF	East Outlet gr/SCF	West Outlet gr/SCF	Stack gr/SCF	Stack lb/10^6 Btu
1	1.03	1.57	0.011	0.019	*	*
2	0.99	1.68	0.007	0.005	0.009	0.018
3	1.34	1.20	0.004	0.008	0.008	0.016
4	2.21	1.36	0.004	0.007	0.012	0.024
5	1.53	1.02	0.001	0.002	0.004	0.007
6	1.36	2.36	0.005	0.042	0.017	0.034

Results of SO_2 Testing EPA Method 6

Run #	East Inlet lb/10^6 Btu	West Inlet lb/10^6 Btu	East Outlet lb/10^6 Btu	West Outlet lb/10^6 Btu	Stack lb/10^6 Btu
2	*	0.91	0.82	0.95	1.10
4	0.98	0.80	0.94	*	*
6	1.10	0.61	0.68	0.64	0.74

Results of NO_x Testing EPA Method 7

Run #	East Inlet lb/10^6 Btu	West Inlet lb/10^6 Btu	East Outlet lb/10^6 Btu	West Outlet lb/10^6 Btu	Stack lb/10^6 Btu
2	*	*	0.60	0.69	*
4	0.55	0.50	0.52	0.53	0.51
6	0.63	0.53	0.48	0.55	0.47

Results of SO_3 Testing EPA Method 8

Run #	East Inlet ppm	West Inlet ppm	East Outlet ppm	West Outlet ppm	Stack ppm
2	0.27	0.79	0.99	0.72	1.10
4	2.07	0.67	0.60	0.82	*
6	2.56	1.96	1.81	1.67	1.86

*No data this run

**Average based on three samples only

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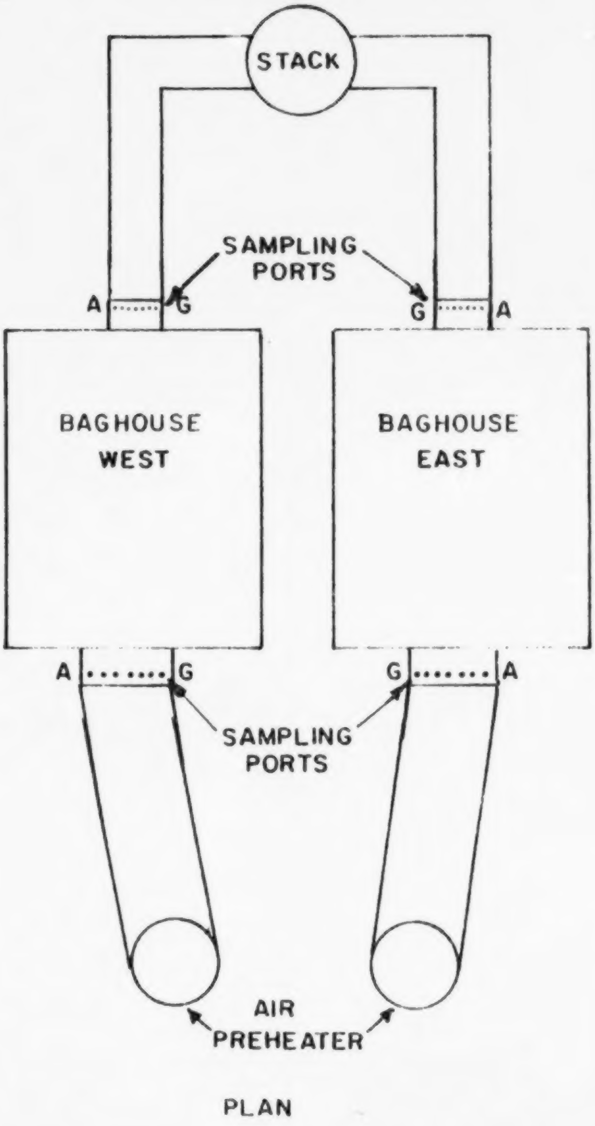
STACK
SAMPLING PORTS
A
G
G
A
BAGHOUSE WEST
BAGHOUSE EAST
A
G
G
A
SAMPLING PORTS
AIR PREHEATER
PLAN

Figure III-12. Sample Port Locations, Unit 2 Plan.

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Performance Standards (NSPS) of 1.2 lb/10^6 Btu; however, the results were erratic, probably because of high negative stack pressures. NO_x emissions were consistent across the entire baghouse. Results of sulfur trioxide tests ranged from 0.3 to 3 ppm.

Particle size distributions were made utilizing Anderson impactors (see Table III-16 for results). The mean particle diameter was determined to be 5.4 microns at the stack exit; mean particle diameters for the east inlet and west inlet were determined to be 3.8 microns and 2.6 microns, respectively. Due to erratic data scatter further testing by impactor is recommended. Figures III-13, III-14, and III-15 show particle size distribution as determined by condensation nuclei counter and optical dust counter techniques.

Difficulties encountered in the sampling of organic emissions prevented GCA from determining a definitive value for organic compounds in organic emissions. Details of the sampling problems encountered are discussed in GCA's draft report. Further study will be necessary to properly evaluate the meaningfulness of this data. GCA's final report will include a more complete analysis of organic sampling. Final revisions to the GCA report are expected to be complete early in the third year of study.

1. Presampling Preparation: All glassware and sample bottles utilized in this test program were cleaned with a laboratory-grade soap solution and then rinsed with tap water, distilled-deionized water, and finally with spectrograde acetone. The glassware was air-dried and capped.

The pitot tube-thermocouple probe assemblies were calibrated in a wind tunnel in the configuration as specified in 40 CFR 60, Appendix A, Method 2, (Federal Register 42,160, 41154, 1977). The meter control boxes were calibrated according to specified procedures and the probe thermocouples were

TABLE III-16. RESULTS OF PARTICULATE SIZE DISTRIBUTION

Sampling Location	West Outlet	East Outlet	Stack	West Inlet	East Inlet
Date	2/9/79	2/9/79	2/9/79	2/9/79	2/9/79
Mean Diameter	4.8	.85	5.1	2.9	1.2
Date	2/12/79	2/12/79	2/12/79	2/12/79	2/12/79
Mean Diameter	*	5.3	5.6	2.3	11.8
Date	2/14/79	2/14/79	2/14/79	2/14/79	2/14/79
Mean Diameter	6.0	*	10.1	1.8	6.4

* NO DATA

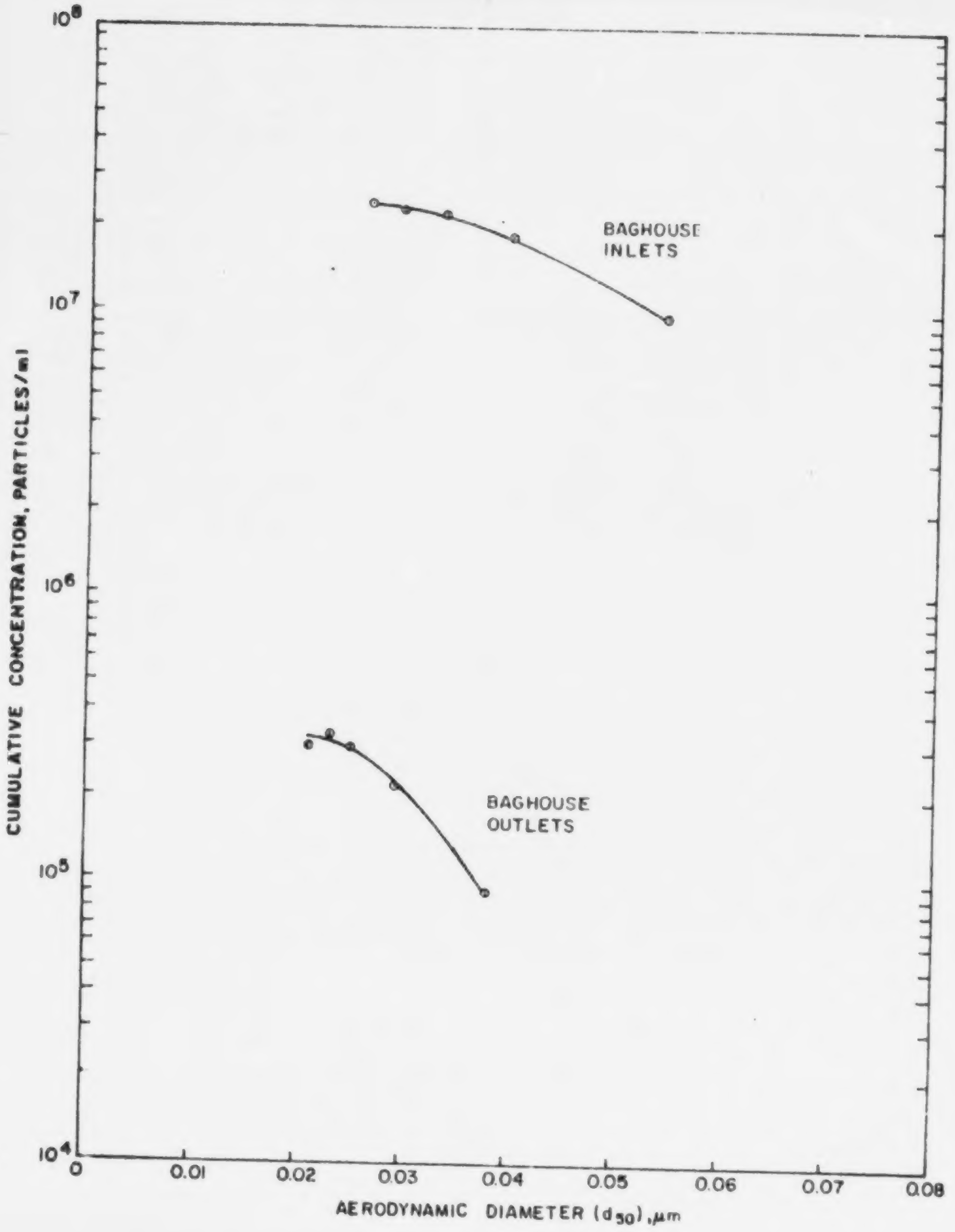

Figure III-13. Averaged Particle Concentrations, Condensation Nuclei.

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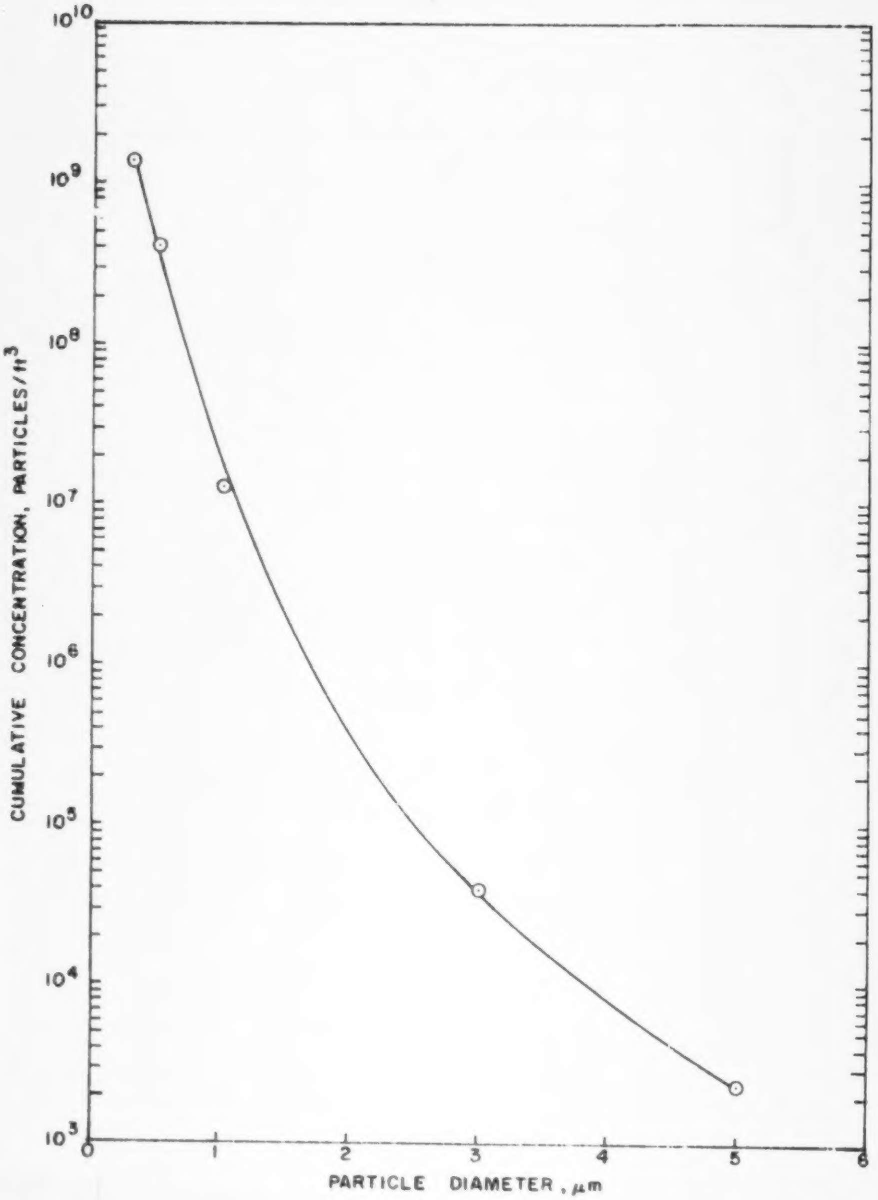

Figure III-14. Averaged Particle Concentrations, Optical Dust Counter, Inlets.

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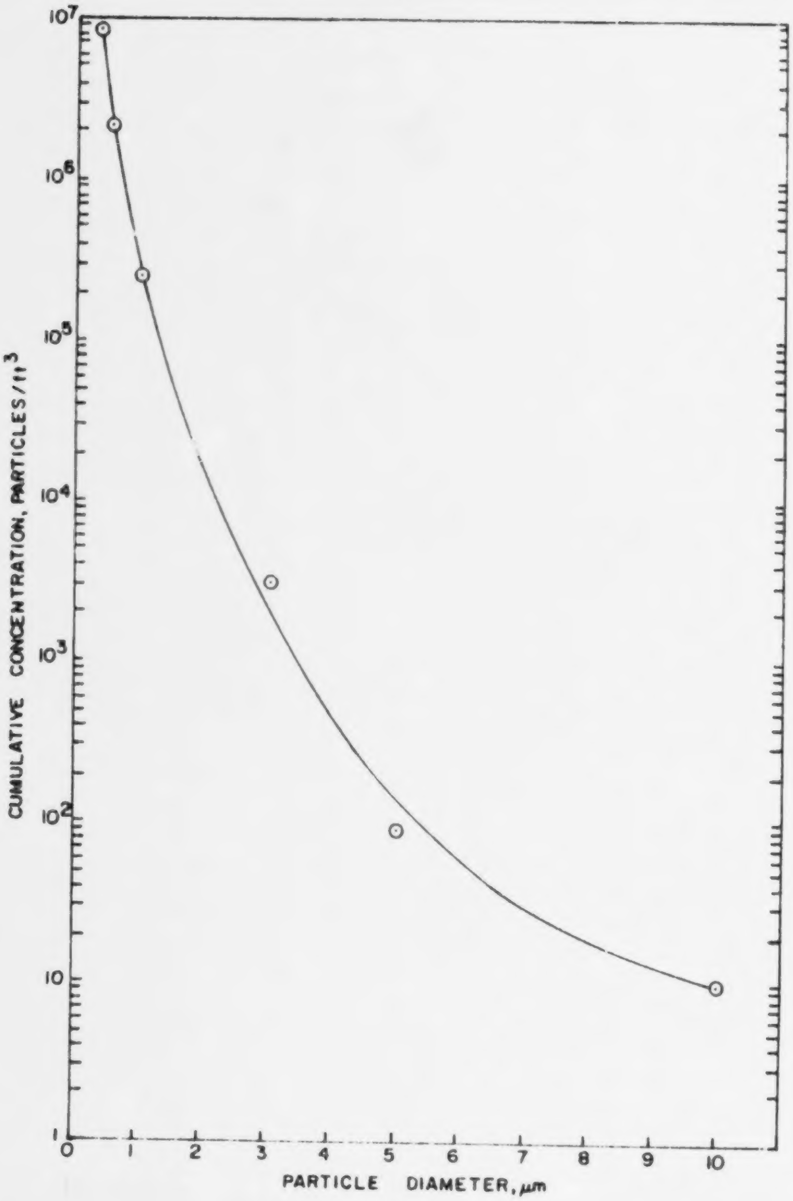


Figure III-15. Averaged Particle Concentrations, Optical Dust Counter, Outlets.

calibrated against a mercury in glass ASTM thermometer in an ice bath and a boiling water bath.

2. Sampling Port and Sampling Point Locations: The FFS consists of two separate units, designated as east and west, each consisting of 14 compartments. Due to this configuration there are two inlet ducts and two outlet ducts. Each outlet duct enters its individual I.D. fan. The outlet breechings from the I.D. fans enter the stack 180° directly opposed to each other.

The inlet ducts are 13 feet, 8 inches wide by 18 feet deep, and the outlet ducts are 13 feet, 8 inches wide by 27 feet deep. Seven vertical ports are installed at each location.

Both the inlet and outlet sampling ports are located directly on duct transition points (Figure III-16) and, therefore, these locations as per EPA Method 1, require a minimum of 48 sampling points for traversing the sampling plane. According to Method 1, however, a balanced matrix is to be used when traversing a rectangular sampling plane and, therefore, at these locations a seven port by seven point matrix was utilized (Figure III-17). The ports in the inlet and outlet ducts are labeled "A" through "G" as shown in Figure III-17. "G" port was located on the inner edge; i.e., the center line of the baghouse.

The sampling ports in the stack are located at the 221 foot level, which is approximately 176 feet above the point where the outlet breechings from the I.D. fans enter the stack. The stack diameter is 20.8 feet and therefore the ports are 8.5 diameters above the inlets to the stack. The ports are also 79 feet below the top of the stack which is equivalent to 3.8 diameters. This location as per EPA Method 1 requires a minimum of 12 sampling points, 6 on a diameter. In order to facilitate simultaneous testing with the other locations, the number of points was increased to 24, 12 on a diameter (Figure III-17).

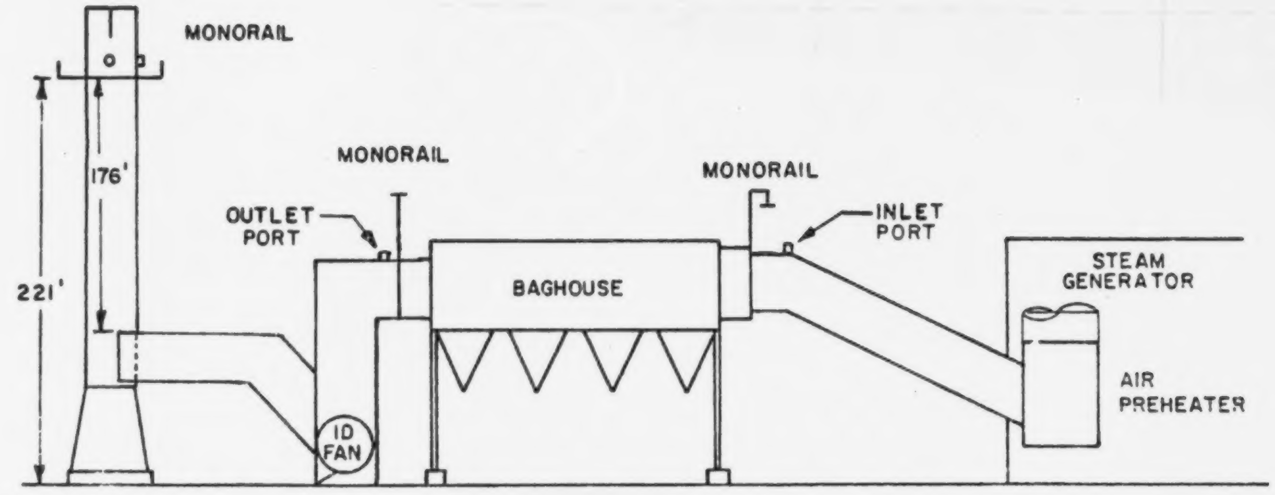
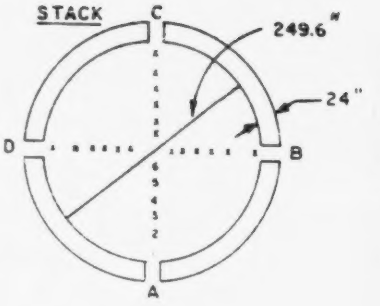

MONORAIL
MONORAIL
MONORAIL
176'
221'
OUTLET PORT
INLET PORT
BAGHOUSE
STEAM GENERATOR
AIR PREHEATER
ID FAN

Figure III-16. Sample Port Locations, West Elevation.


STACK
C
249.6"
24"
D
B
A
6
5
4
3
2

Point	STACK Distance from inner wall in inches
1	5-4/16
2	16-12/16
3	29-7/16
4	44-3/16
5	62-6/16
6	88-14/16

Point	INLET Distance from inside wall in inches	OUTLET Distance from inside wall in inches
1	15-7/16	23-2/16
2	-6-5/16	69-7/16
3	77-2/16	115-11/16
4	108-0/16	162-0/16
5	138-14/16	208-5/16
6	169-11/16	254-9/16
7	200-9/16	300-14/16

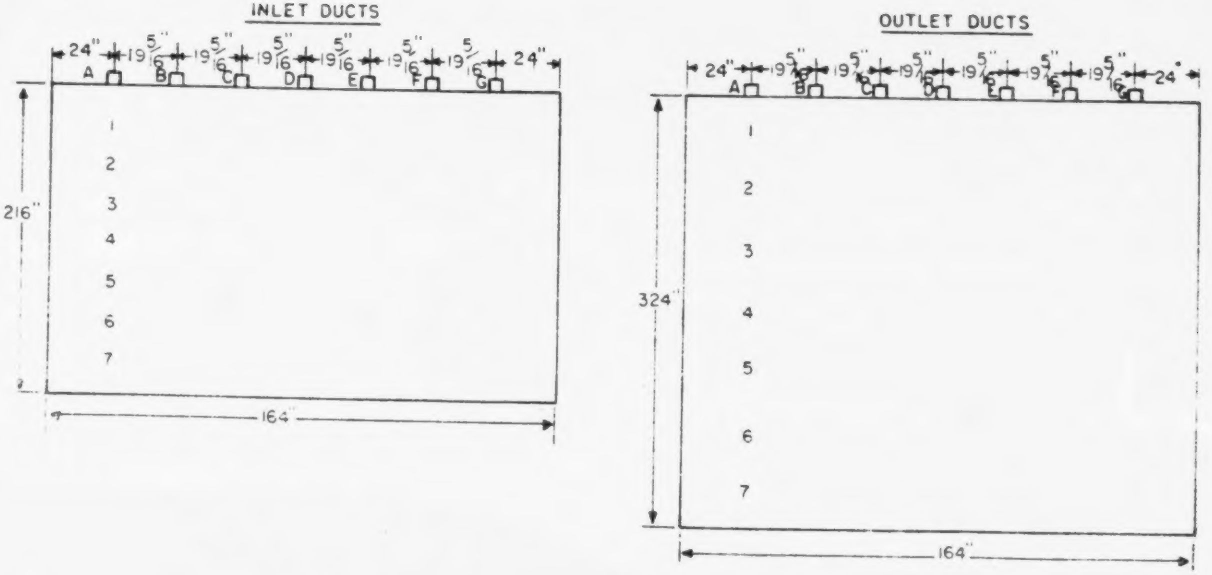

INLET DUCTS
24"
19 5/16"
A
B
C
D
E
F
G
24"
1
2
3
4
5
6
7
216"
164"
OUTLET DUCTS
24"
19 5/16"
A
B
C
D
E
F
G
24"
1
2
3
4
5
6
7
324"
164"

Figure III-17. Sampling Point Locations.

3. Sampling and Analytical Procedures: The gas stream at each sampling location was sampled for particulates, C_7-C_{17} organic compounds, C_1-C_6 organic compounds, CO_2, O_2, CO, SO_2, SO_3, NO_x and particle size distribution. Samples of baghouse hopper ash and raw coal fired during each test were also obtained.

To facilitate testing, sampling procedures were grouped as described below and were conducted on alternate days. A total of three test runs for each group was conducted.

A GROUP

Method 5 - Particulates and C_7-C_{17} Organics
Method 3 - CO_2, O_2, CO and C_1-C_6 Organics
Particle Size Methods

B GROUP

Method 8 - SO_3 and SO_2
Method 3 - CO_2, O_2 and CO
Method 6 - SO_2
Method 7 - NO_x

4. Preliminary Traverse: A preliminary velocity and temperature traverse and cyclonic flow check utilizing a type S pitot tube and a thermocouple was conducted at all sampling locations as per EPA Methods 1 and 2. These data were utilized to properly size the probe nozzle and adjust the nomograph for isokinetic sampling, as well as to confirm the absence of cyclonic flow. The type S pitot tube, common to the EPA-approved sampling train, is considered the accepted flow measuring device in a gas stream containing particulate emis-

sions. The pitot tube utilized during the test program, was calibrated against a standard pitot tube under controlled conditions in a laboratory wind tunnel. The coefficient (c_p) obtained was between 0.842 and 0.859. The nominal coefficient (c_p) for type S pitot tubes calibrated in this manner is 0.85 ± 0.02. Therefore, the pitot tubes used were within the nominal range.

5. Measurements of Total Particulate Matter: The particulate matter was withdrawn isokinetically from each of the sampling points in Figure III-17 and its weight determined gravimetrically after removal of uncombined water. The particulate sampling and analysis procedures were in accordance with 40 CFR 60 Appendix A, Methods 1 through 5, Determination of Particulate Emissions from Stationary Sources.

Due to the requirement for extremely long probes at the inlet and outlet locations, Method 5 was modified to the in situ sampling procedure identified as Method 17. The primary particulate collecting component was an in situ glass fiber thimble. The organic sampling and analyses were made by a modification of EPA Level 1 procedures for C_7-C_{17} organic compounds.

The sampling trains conformed to Method 5 specifications with modifications (see Figure III-18). For the inlet and outlet locations only the probe buttonhook nozzle was followed by a 19-inch long 316 stainless steel 5/8 inch OD tube connected via a U-piece of the same material to an in-stack stainless steel thimble holder in the upright position. Another U-shaped piece of tubing connected the thimble holder to the probe.

The particulates (as well as C_7-C_{17} and $> C_{17}$ organic compounds) were sampled over 49 points at the inlet and outlet duct locations with a sample duration of 3 minutes/point for runs 1, 2, 3, 4, and 6, and for 5 minutes/point for run 5 for a total test run time to 144 and 245 minutes, respectively. At the stack location, sampling was conducted over 24 points

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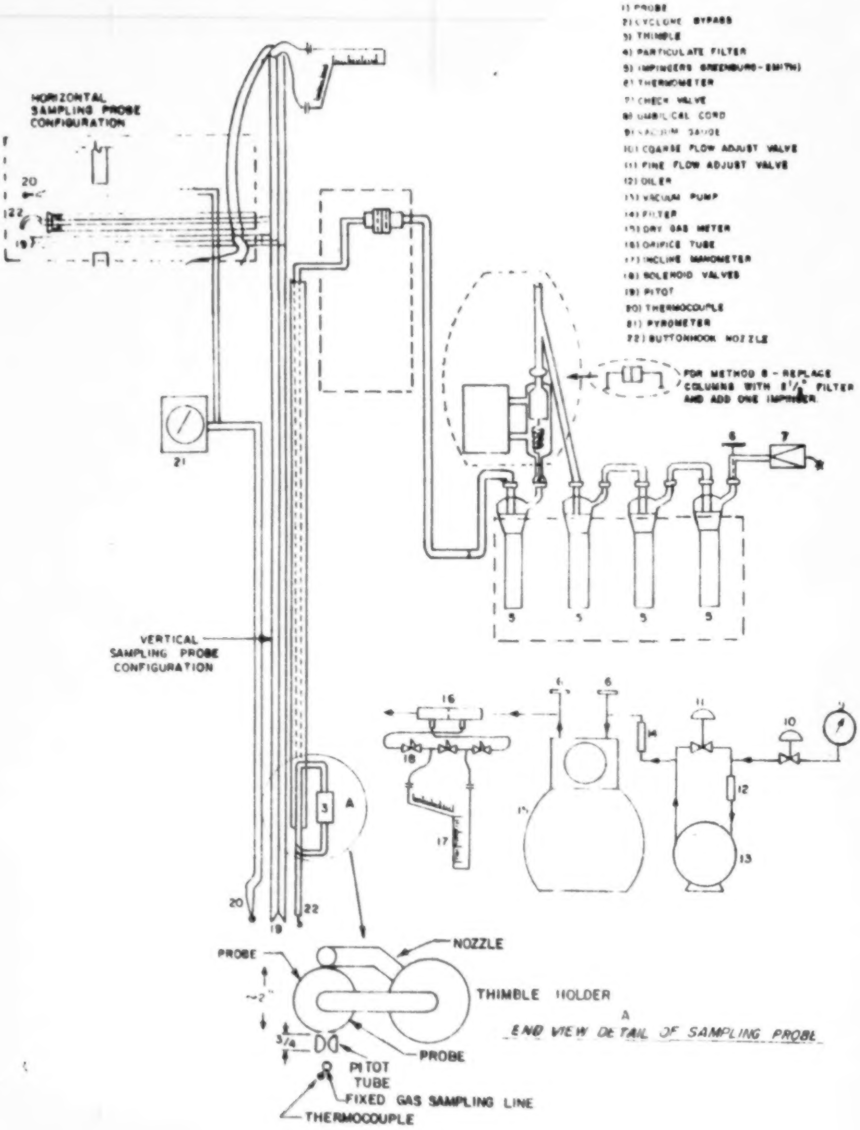
1) PROBE
2) CYCLONE BYPASS
3) THIMBLE
4) PARTICULATE FILTER
5) IMPINGERS (GREENBURG-SMITH)
6) THERMOMETER
7) CHECK VALVE
8) UMBILICAL CORD
9) VACUUM GAUGE
10) COARSE FLOW ADJUST VALVE
11) FINE FLOW ADJUST VALVE
12) OILER
13) VACUUM PUMP
14) FILTER
15) DRY GAS METER
16) ORIFICE TUBE
17) INCLINE MANOMETER
18) SOLENOID VALVES
19) PITOT
20) THERMOCOUPLE
21) PYROMETER
22) BUTTONHOOK NOZZLE
HORIZONTAL SAMPLING PROBE CONFIGURATION
FOR METHOD 8 - REPLACE COLUMNS WITH 2 1/2" FILTER AND ADD ONE IMPINGER.
VERTICAL SAMPLING PROBE CONFIGURATION
PROBE
NOZZLE
THIMBLE HOLDER
~2"
3/4
PITOT TUBE
FIXED GAS SAMPLING LINE
THERMOCOUPLE
A
END VIEW DETAIL OF SAMPLING PROBE
20
22
19
21
3
5
6
7
16
18
17
15
14
11
10
12
13

Figure III-18. Methods 5 and 8 Sampling Trains.

with a sample duration of 6 minutes/point for runs 2, 3, 4, and 6, and 10 minutes/point for run 5 for a total test time of 144 minutes and 240 minutes respectively. Three test runs constituted the test. Sampling proceeded at all locations simultaneously. A nomograph equating velocity pressure ΔP, with sampling rate ΔH, was used to obtain the required ΔH for a given ΔP, in order to sample isokinetically.

A leak-check of the entire sampling train was conducted prior to and after each sampling run and before and after changing or disconnecting any components of the train during the run. The leak-check before the test run and after changing any constitutent was conducted at 15 inches Hg vacuum to ensure a leak rate of no more than 0.02 cfm. The leak-checks conducted at the end of a run and prior to making any component changes or disconnecting them to facilitate moving the train were at the highest vacuum obtained during the run. The pitot tube assembly was also leak checked prior to and after each sampling run to ensure the validity of the velocity determinations. The leak checks were conducted at the conclusion of the test run before disassembly for sample recovery.

The analysis of the samples for particulates proceeded as follows. The acetone washes were transferred to tared 250 ml beakers and air dried at ambient temperature and pressure in a hood. After removal of the acetone, the residue was desiccated to a constant weight over drierite. The glass fiber thimbles and filters were also desiccated to constant weight over drierite. An acetone blank was processed in the same manner as the samples and a blank correction was made for all residues.

6. Measurement of Sulfur Dioxide - EPA Method 6: The midget impinger train as shown in Figure III-19 was used at all five sampling locations. At the inlet and outlet locations, the probe was a heat-traced, 3/8 x 0.65 inch wall 316 stainless steel liner 15 feet long and 22 feet long, respec-

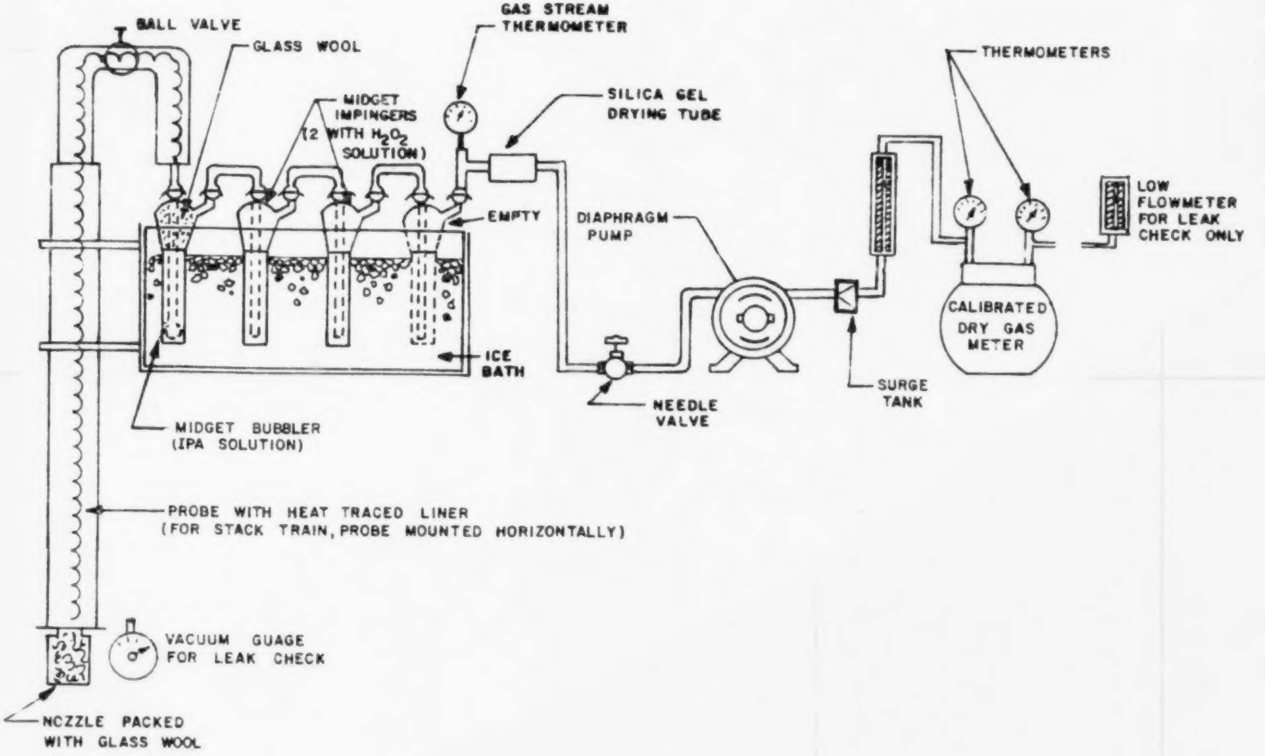
BALL VALVE
GLASS WOOL
MIDGET IMPINGERS (2 WITH H_2O_2 SOLUTION)
GAS STREAM THERMOMETER
SILICA GEL DRYING TUBE
THERMOMETERS
LOW FLOWMETER FOR LEAK CHECK ONLY
EMPTY
DIAPHRAGM PUMP
ICE BATH
CALIBRATED DRY GAS METER
NEEDLE VALVE
SURGE TANK
MIDGET BUBBLER (IPA SOLUTION)
PROBE WITH HEAT TRACED LINER (FOR STACK TRAIN, PROBE MOUNTED HORIZONTALLY)
VACUUM GUAGE FOR LEAK CHECK
NOZZLE PACKED WITH GLASS WOOL

Figure III-19. Method 6 — Sulfur Dioxide Sampling Train.

tively. A 10-foot heat traced 3/8 inch O.D. x 0.65 inch wall 316 stainless steel liner was used at the stack location. Glass wool was placed in front of the probe to filter out all particulates. Due to the relatively high negative static pressure that were encountered at both the inlet and outlet locations, a stainless steel shutoff valve had been installed on the outlet of the probe. This was to prevent the back flow of the impinger solutions when the sampling pump was not running. Following the valve was a glass right-angle connector and four midget impingers in an ice bath. The first impinger had been modified with a coarse fritted bubbler and contained 15 ml 80 percent isopropanol. Glass wool was placed in the outlet arm to act as a demister. The next two impingers were of the standard small orifice type and each contained 15 ml of 3 percent H_2O_2. The fourth impinger was empty. The impingers were maintained in an ice bath. Attached to the last impinger was a stainless steel junction which was connected to a drying tube for removal of any remaining moisture. Vacuum tubing connected the train to the pump which was followed by a rotameter and a dry gas meter.

A sampling point of average velocity and temperature was determined by analysis of Methods 1 through 5 sampling data. The sampling train was assembled and leak checked according to Section 4 of EPA Method 6 and the probe tip was positioned at the selected sampling point. With the sampling valve in the off position, the pump was run to provide a vacuum greater than or equal to the negative pressure at the sampling point. The sampling valve was then opened and the sampling flow rate adjusted to 1.0 liter per minute as indicated by a rotameter. Sampling continued for 30 minutes and data (temperatures, sample flow, and dry gas volume) were recorded every 5 minutes. At the conclusion of the run, a leak check was performed, the probe disconnected, the ice was removed, and the train was purged with ambient air for 15 minutes.

The contents of the first impinger were discarded. The contents of impingers 2, 3, and 4 were transferred to a polyethylene bottle and the impingers were rinsed three times with distilled, deionized water. A blank sample of the H_2O_2 was taken for each sampling run.

The H_2O_2 samples were analyzed in triplicate by the barium perchlorate-thorin indicator titration.

Two 30-minute sampling runs were conducted back to back for each measurement. The resulting concentrations were averaged and this value was reported.

7. Measurement of Nitrogen Oxides - EPA Method 7: EPA Method 7 was employed to determine the nitrogen oxide emissions. Sampling was conducted at the same point in the ducts and stack as used for Method 6. The probes utilized at all locations were those used for Method 6.

The sampling apparatus is shown in Figure III-20. Due to the high negative pressure existing at the baghouse inlet and outlet sampling locations, a vacuum pump replaced the squeeze bulb for the purpose of purging the train of any condensation that may have occurred in the probe and flask valve area.

The sampling train was composed of the probe with shut-off valve, a flask with a three-way stopcock, a T attached to a 36-inch U-tube manometer, another three-way stopcock, and a vacuum pump.

Sampling proceeded as follows: 25 ml of 0.1N H_2SO_4 containing 3 percent H_2O_2 was added to the flask. The flask was then evacuated to a net pressure of less than 3 inches Hg (27 inches Hg vacuum). The flask was checked for leaks by observing the change in pressure when the vacuum pump was removed from the system. If there was no change in pressure for 1 minute, the flask was said to be leakproof. The probe was purged with the vacuum pump. The pressure in the flask was checked and the temperature of the flask was noted. The three-way stopcock on the flask was opened to the probe and

TYPING GUIDE SHEET

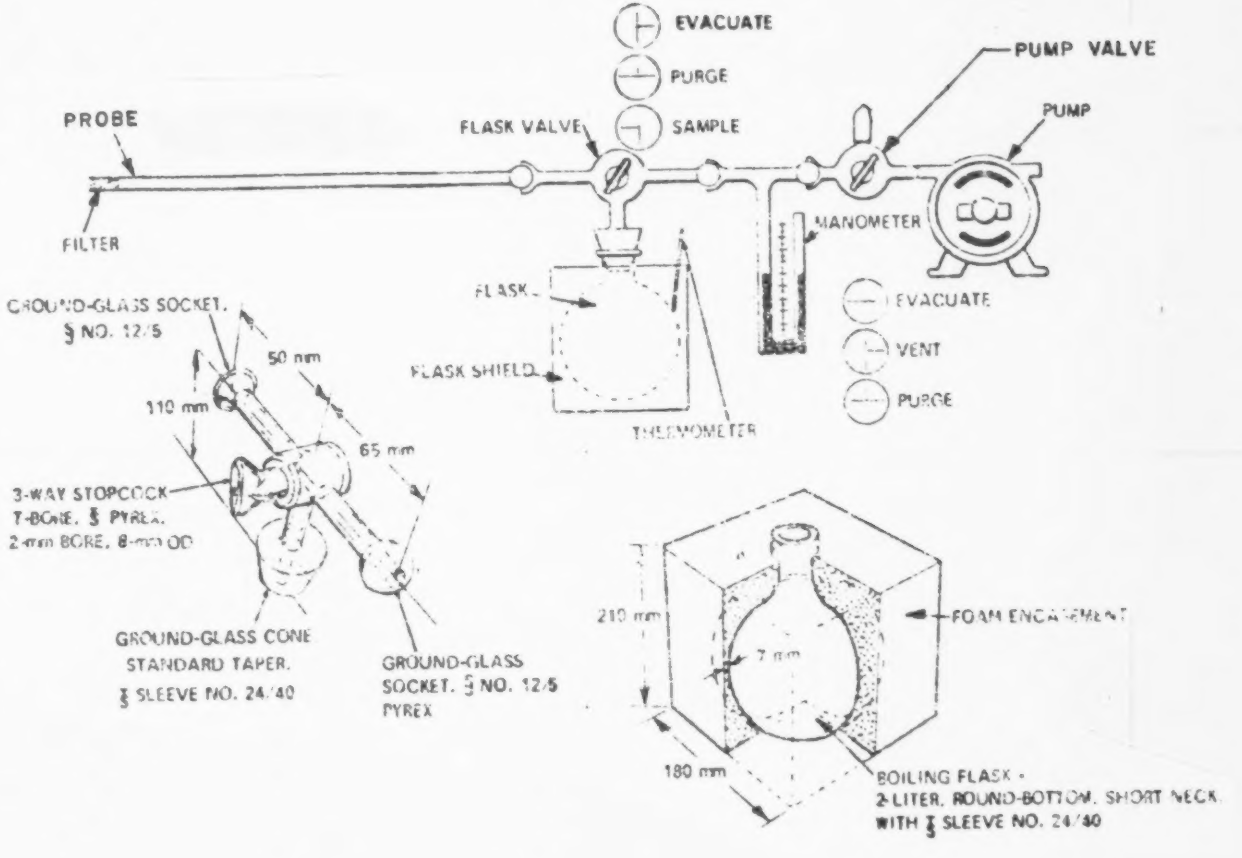
EVACUATE
PURGE
SAMPLE
PUMP VALVE
PUMP
PROBE
FLASK VALVE
FILTER
MANOMETER
FLASK
FLASK SHIELD
THERMOMETER
EVACUATE
VENT
PURGE
GROUND-GLASS SOCKET. § NO. 12/5
50 mm
110 mm
65 mm
3-WAY STOPCOCK T-BORE. § PYREX. 2-mm BORE, 8-mm OD
GROUND-GLASS CONE STANDARD TAPER. § SLEEVE NO. 24/40
GROUND-GLASS SOCKET. § NO. 12/5 PYREX
210 mm
7 mm
180 mm
FOAM ENCASEMENT
BOILING FLASK - 2-LITER, ROUND-BOTTOM, SHORT NECK, WITH § SLEEVE NO. 24/40

Figure III-20. Method 7 — Nitrogen Oxides Sampling Train.

the sample was drawn into the flask for 15 seconds. The stopcock was closed and the flask removed. For each test run a total of four NO_x grab samples were collected at each sampling location. One sample was obtained every 15 minutes. The samples were analyzed colorimetrically by the phenol-disulphonic acid procedure. The average of the four samples obtained on a given day were reported for each run.

8. Baghouse Hopper Ash Sample: Individual ash samples were collected from 12 of the 28 baghouse collecting hoppers. The hoppers were sampled at the midpoint of each Method 5 or Method 8 test run. Individual samples were of equivalent volume and were stored in quart Mason jars for compositing. The individual samples were combined into two 1-gallon bottles. This combined daily sample was riffled in the GCA/Technology Division Laboratory and split into two samples. One sample was analyzed by Gilbert Associates, Reading, Penn., for loss on ignition by ASME PTC 28, and carbon and hydrogen content by ASTM D-3178. The other sample was analyzed for metallic elements and inorganic compounds in the GCA Laboratory.

9. Raw Coal Sample: Raw coal samples were obtained by Southwestern Public Service personnel from the five belt feeders prior to the entry point into the pulverizers. Samples were obtained from each feeder three times during each Method 5 and Method 8 sampling runs. The individual feeder samples were composited, ground, riffled, and split into two 1-gallon subsample containers by Southwestern, one of which was received by GCA.

The GCA sample was riffled and split into two samples. One sample was sent to Gilbert Associates, Reading, Pennsylvania, for the following: Btu per pound, proximate and ultimate analysis, according to ASTM procedures D2015, D3172, and D3176, respectively. Due to the sparking nature of the coal, the volatile matter was determined by ASTM D1375. The sulfur content was determined on a sulfur analyzer and standardized against a National Bureau of Standards and Bureau of Mines Standard Reference Coal.

The sample retained by GCA was subjected to the same elemental and inorganic compound analysis as for the hopper ash.

C. Test Program Summary

During the second year of study, the first round of special testing as called for in the Scope of Work was completed. Certain problems were identified that will need to be resolved before the second set of tests are run. However, Southwestern feels this first-time experience will enable its testing personnel to perform more efficiently and with greater confidence on tests planned for the third year of study.

Southwestern feels that in the future, it may be possible to obtain adequate results with less testing. Certain sampling techniques have yet to be perfected; therefore, data from these tests may be of questionable value, especially in scaling information from one power plant to another. Southwestern has suggested it may be more beneficial and less expensive to continue to limit future simultaneous sampling of particulate and SO_2 to three points (two inlets and the stack) as well as NO_x, which was sampled at five locations during the first series of testing. Southwestern and EPA will consider these changes before the next series of tests are conducted.

IV. FABRIC ASSESSMENT

The fabric filter system on Harrington Unit 2 was the first of its kind. In addition to being the world's first fabric filter on a new utility boiler, it was also the first on a large utility boiler designed to handle Western coal from the Powder River Basin. Obviously, the selection of a fabric for this installation facility could not be based on past experience. The process of fabric selection for initial installation was, in short, a stab in the dark.

After the first several months of operation it became apparent that the original choice of fabric was not going to give the expected pressure drop. Several more months of operation also made it clear that the fabric was experiencing a high rate of failure.

The failure of the original fabric made it necessary for Southwestern to engage in a fabric filter evaluation program in order to find a fabric that would give satisfactory performance.

A. Fabric Filter Test Program

As part of Southwestern's fabric evaluation program, test bags were periodically removed from test compartments and sent to the Environmental Consultant Company of Phoenix, Arizona for evaluation.

Specifications for the fabrics tested are shown in Table IV-1. The bags were tested for indications of mechanical failure by MIT Flex, Mullen Burst and Breaking Strength. Pluggage was determined by running permeability on the cloth

TABLE IV-1. FABRIC SPECIFICATIONS

MANUFACT.	STYLE	FINISH	WT	COUNT	WEAVE	PERM	YARN	YARN
Criswell	445	04	10.5	64X32	3X1T	50-60	150-1/2 F	37-1/0 T
Criswell	442	Teflon	10	55X31	3X1T	50-60	150-1/2 F	150-2/2 T
Criswell	449	Burlington I580	13.2	44X24	3X1T	50-65	75-1/2	75-1/3 T
Criswell	449	COF	13.2	44X24	3X1T	50-65	75-1/2	75-1/3 T
Fabric Filters	502-1	Tri-Treat	13.2	44X24	3X1T	50-65	37-1/0	75-1/3 T
Fabric Filters	502-1	Acid Flex	13.2	44X24	3X1T	50-65	37-1/0	75-1/3 T
Fabric Filters	502-1	Acid Flex/ Gore-Tex	13.2	44X24	3X1T	50-65	37-1/0	75-1/3 T
Menardi-Southern	601	Teflon	10	54X30	3X1T	47-70	150-1/2	150-2/2
Globe Albany	5-3014	Permaguard 6	5.5	82X72	3X2T	60-80	Cotton Spun Single	Cotton Spun Single

as received, after being vacuumed and finally after being washed. The condition of the fabric coating was determined by Loss on Ignition (LOI) and in some cases, by microscopic examination. The results of these tests are presented in Table IV-2.

The original fabric installed in the FFS was W. W. Criswell's style 445-04 (Item #3, Table IV-2). Permeability determinations on an as received basis (see Table IV-2) revealed that the fabric plugged soon after start-up. The system pressure drop was equivalent to 3 inches w.g. over design after start-up and continued to get worse until the fabric was replaced in the summer of 1979.

From Table IV-2 it is apparent that the mechanical properties of the 445-04 fabric also deteriorated rapidly to unacceptable levels. The MIT Flex fell by over 90 percent. Breaking Strength and Mullen Burst results showed less drastic declines.

The most surprising test result was due to the dramatic change in the LOI values for the 445-04 fabric. As shown in Table IV-2, nearly 60 percent of the coating was found to be degraded after the fabric was in service only a short time. Special tests conducted by Environmental Consultants established that the material burning off was sizing which had not been removed from the fabric before the graphite/ silicone coating was applied. Subsequent investigation revealed that the fabric had not been heat cleaned or coronized before the finish was applied. Since the coating was applied on top of the sizing, degradation of the sizing certainly must have left the lubrication properties of the coating in doubt. In addition to causing failure of the coating, the lack of heat treating or coronizing also affected the dimensional stability of the fabric.

Soon after start-up, it became apparent that stretching of the original fabric was also a problem. A series of tests

TABLE IV-2. SUMMARY OF BAG TESTING RESULTS

Bag Type	Date	Perm. As Received	Perm. Cleaned (Vacuum)	Breaking Strength (lbs/inch) Warp/Length	Breaking Strength (lbs/inch) Filling/Width	PSI Mullen Burst	% LOI	Flex MIT Warp	Flex MIT Fill
1. FF Acid Flex	10-13-78	57.50*	—	643	307	710	4.36	10,745	—
	10-13-78	1.30	38.0	518	262	541	4.12	5.231	—
	1-22-79	1.85	39.2	484	271	526	4.09	5,349	—
	9-12-79	1.00	34.2	454	229	464	3.87	3,812	1,489
2. FF Tri-Treat	10-13-78	61.00*	—	561	287	538	2.56	3,785	—
	10-13-78	1.30	38.0	518	262	541	2.34	5,231	—
	1-22-79	1.95	40.1	392	216	274	2.31	1,896	—
	9-12-79	1.41	42.1	229	113	313	1.91	545	244
	9-26-79	69.50*	—	561	293	748	2.58	5,897	1,924
3. Criswell 445-04 (Original Bags)	10-13-78	58.60*	—	389	146	498	2.95	4,698	—
	10-13-78	1.28	39.2	265	118	250	1.53	292	—
	1-22-79	2.20	39.6	112	48	112	1.21	118	—
	2-05-79	1.28	41.3	94	41	175	1.42	42	—
	2-05-79	1.30	38.7	131	54	152	1.23	110	—
	2-05-79	1.28	41.3	108	42	187	1.28	105	—
	5-07-79	2.17	33.6	188	100	311	1.13	1,492	203
	5-07-79	2.08	41.1	178	99	315	1.08	1,019	196
	5-07-79	1.95	34.1	156	66	225	1.09	338	102
4. Menardi-Southern 601-Teflon	9-26-79	62.50*	—	249	132	538	9.31	15,861	521
5. Criswell 442 Teflon B (Warp In)	9-26-79	48.50*	—	238	124	508	8.97	21,881	548
6. Criswell 449-580	9-26-79	72.50*	—	537	281	752	2.67	5,842	1,527
7. Criswell 449-580 (Warp In)	7-25-79	Less 1	18.7	202	195	596	8.80	4,704	5,020
8. Criswell 442 Teflon B	3-07-79	2.70	37.9	199	166	320	9.27	13,046	594
	5-07-79	2.28	35.3	191	134	353	8.94	7,875	369
	9-06-79	1.39	32.6	178	77	281	—	2,610	242
	9-26-79	48.50*	—	238	124	508	8.97	21,881	548
9. Gore Tex	9-06-79	2.50	6.2	630	320	815	4.32	25,000	10,000
10. Perma Guard (Nomex)	9-26-79	61.20*	—	167	144	424	5.80	98,874	86,071
11. Criswell 449 (Crissoflex)	9-06-79	Less 1	34.6	525	260	545	—	6,383	2,214
	9-06-79	Less 1	30.1	475	273	593	—	6,342	2,176
	9-06-79	1.56	32.9	516	306	634	—	8,241	2,069
	9-26-79	69.90*	—	587	309	863	6.41	72,438	9,101

*New Bag

was run by Wheelabrator Frye, Inc. (WFI) at their R&D Laboratory in Mishawaka, Indiana, to investigate the extent of stretching vs load on the Criswell 445-04 fabric with several different coatings. Full length bags were loaded to various degrees and elongation measured as a function of load. The results of these tests are shown in Figure IV-1.

As can be seen in this figure, the graphite/silicone coated fabric stretched a remarkable 7 inches after being tensioned to 60 pounds. Table IV-3 shows elongation at 60 pounds tension vs percent coating reveals a linear relationship between the amount of coating and the stretch characteristics of the fabric. It appears then that the amount of coating acts in some way to retard the ability of the fabric to stretch under tension.

Because of the stretching characteristics of the original fabric, it became virtually impossible to maintain proper tension on the fabric. A freshly-tensioned compartment of bags required retensioning shortly after being put back in service. Inspections revealed that the bags "bloused" over the thimble and caused sharp double folds in the fabric which, in conjunction with the generally weak mechanical properties of the fabric, gave rise to the many "pinhole" type failures observed at the cuff area.

In addition to tests run on the original fabric, Table IV-2 contains the results of tests done on a set of 34 test bags placed in compartment 22 for endurance evaluation. Item #1 on Table IV-2 records the results of testing on Fabric Filters Acid Flex bags taken from this compartment. Although the MIT Flex suffered a substantial drop initially, it did not drop as far as the original fabric and it remained in good shape throughout the testing period. This material appears to be a good candidate for a long life bag. Higher flow through the bag may have affected permeability numbers.

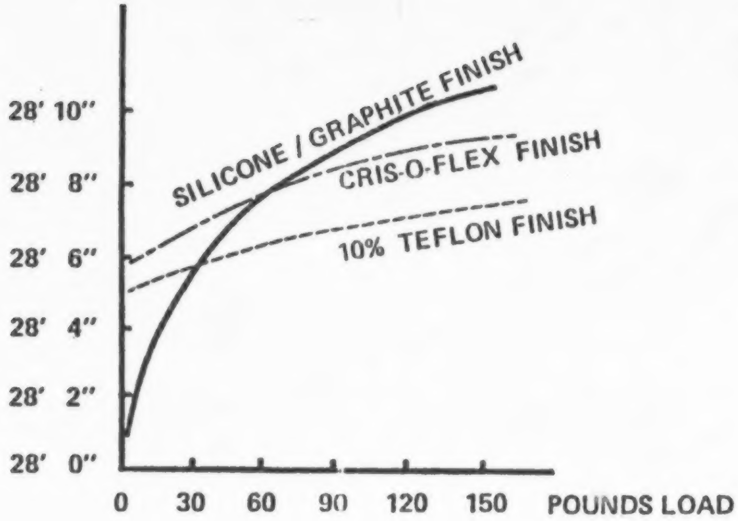

Figure IV-1. Stretching Curves for Glass Cloth.

TABLE IV-3. STRETCH VS % COATING ON CRISWELL 445 FABRIC*

% Elongation	% Coating
2.0	1.30
0.59	5.78
0.37	9.50

* At 60 lbs. tension

Item #2 on Table IV-2 is a record of the results of testing on samples of Fabric Filters Tri-Treat test bags from compartment 22. The table indicates the mechanical properties of the Tri-Treat fabric are by no means equal to the Acid Flex fabric but vastly superior to the original fabric. Again, the permeability figures may be misleading due to higher flow rates.

Items #7 and #11 are the results of testing special fabrics installed in compartment 7 along with the original fabric. Again, the mechanical properties appear to be superior to the original fabric.

Items #4, #5, #9 and #10 are the results of testing fabric that has not been in service for comparison purposes. Future testing on these fabrics will be of great interest.

Item #8 records the results of testing samples from compartment 21 which was rebagged in late January, 1979, with a Teflon-coated fiberglass fabric. The testing indicates that the fabric does not blind as much as the other fabrics with the permeability being 25 percent higher. The MIT Flex, Mullen Burst and Breaking Strength tests all indicate that the fabric did not degrade as rapidly as the original fabric. This fabric appears to be an excellent candidate for good pressure drop performance.

B. Special WFI/Southwestern Study

In a meeting between Wheelabrator-Frye, Inc. (WFI) and Southwestern representatives held on May 15, 1979, the question of the distribution of dust by particle size along the length of the bag was brought up and plans were made to remove test bags from a compartment to study this phenomenon. As a result, two bags, one from the corner and one from the middle, were removed from compartment 13 and tied off in thirds. The two sample bags were sent to the WFI R&D Laboratory in Mishawaka, Indiana. Moisture, helium pycnometer density, and particle size by A-B Sonic Sifter and Bahco micro particle classifer were determined on six samples of fly ash (see Appendix B for the complete WFI report). In addition, scanning electron micrographs were made of samples of the fly ash, dust cake and cloth (included in Appendix B).

The WFI study pointed out several very interesting findings. The dust cake found on the bags was almost constant in weight from top to bottom. Of even greater interest was discovering that the particle size distribution in the bag was also constant from top to bottom with the average particle size being 5.7 microns mass median diameter.

The results of the scanning electron microscope showed that the fly ash had a tendency to agglomerate. Rather than form close, packed, dense cakes, the fly ash particles seemed to prefer to land on their own kind and form an open dendritic structure. This phenomenon had been observed previously and is thought to prevent the fabric from plugging.

C. Acurex Mobil Baghouse Study

As a part of the fabric assessment phase of the FFS study, Acurex Corporation was asked by the EPA to bring a mobile fabric filter to Amarillo and conduct evaluation tests on a variety of fabrics. During the spring of 1979, the mobile unit was connected to a slipstream from Unit 1 at Harrington to evaluate the following fabrics which were selected by Southwestern:

1. W. W. Criswell silicone-graphite coated fiberglass, style 445-04 (original bag installed in Harrington Unit 2 baghouse).
2. W. W. Criswell Teflon B coated fiberglass, style 442-570C2.
3. Menardi-Southern Teflon B coated fiberglass, style MS-601.

4. Fabric Filter Acid Flex fiberglass, style 504-1.
5. Fabric Filter all filament fiberglass, style 50G-ITC.
6. Fabric Filter Gore Tex laminate fiberglass.
7. Menardi-Southern Teflon B coated fiberglass, reverse-air bags with spreader rings.

The mobile fabric filter took a slipstream from Unit 1 rather than Unit 2 because Unit 2 was scheduled for overhaul during part of the evaluation period. Since the two units are identical, the data obtained were considered to be representative of operation on Unit 2. Acurex studied the following parameters to determine the effectiveness of:

1. Increased shaking frequency.
2. Reverse air cleaning.
3. Using ringed bags.

The recommendations made by Acurex to Southwestern following the study were as follows:

1. Evaluate higher shake frequencies and monitor bags at quarterly intervals via diagnostic tests, (i.e., Mullen Burst, Tensile Strength, etc.).
2. Evaluate performance characteristics of Acid Flex or an equivalent fabric.
3. Evaluate performance characteristics of higher deflation pressures with ring bags.

The complete Acurex report to Southwestern is included as Appendix C.

D. Selection of Replacement Fabrics

An accelerated bag failure rate was the major factor in the decision to rebag the Unit 2 FFS before the summer peak load of 1979. By this time Southwestern had experience with only a handful of fabrics and it was felt that this was not sufficient data to choose a best fabric. Therefore, Southwestern decided to rebag the FFS with a variety of fabrics so that experience could be gained that would allow Southwestern to make a better selection in the future.

E. Flow Measurements

One of the most significant variables affecting the performance of any given compartment of fabric is the gas flow rate through that compartment. In order to get a handle on compartment flow, compartments 19-24 were instrumented with manometer taps across the outlet damper. During the rebagging outage, four additional manometer taps were placed in the west baghouse (compartments 5, 6, 7, and 8) across the outlet damper. When the east baghouse was brought off line for rebagging, three additional manometer taps were installed in compartments 25, 26, and 27. These were located exactly like those in the west baghouse. Flow measurements were made by connecting a portable manometer to the tap across the compartment outlet dampers.

The analysis of this data is complicated by the fact that the values change from day to day with load changes. Looking at the flow manometer data may also give a misleading impression about how significant any given differences in readings are since flow is actually proportional to the square root of these numbers.

To overcome these problems it was decided to define the relative flow number as the square root of the manometer reading for the compartment divided by the square root of the manometer reading for a comparison compartment. The comparison compartment was defined as the average of compartments 7 and 10, which both contain Criswell's 442 10-ounce Teflon fabric. The relative flow number then is given by:

$$\text{relative flow number for compartment } i = (h_i / h_{ref})^{0.5}$$

where h is the average for compartments 7 and 10. A relative flow number of 1.15 then would indicate 15 percent more flow through the compartment than for a compartment containing W. W. Criswell 442 Teflon bags. The average of all of the relative flow numbers for the various test fabrics is shown in Table IV-4.

The following is a summary of flow measurement findings:

1. Compartment 6 to date indicates slightly better performance with the Menardi-Southern fabric.
2. Compartment 9 with "warp in" indicates very poor performance.
3. Compartment 20 with "warp in" also does not yield good results.
4. Compartment 24 has outstanding performance and if the acid dew point does not present a problem later, this fabric should have excellent life.
5. The 6-inch pulley system (rapid shake) yields excellent improvement in performance.

After the installation of manometers in each of the compartment outlet dampers, the definition of h_{ref} will include all of the compartment data. The definition of R_i will be changed to

$$R_i = \sqrt{h_i} / \left(\sum_{1}^{N} \sqrt{h_i} / N \right)$$

where N = # of compartments.

TABLE IV-4. FLOW MEASUREMENTS FOR TEST COMPARTMENTS

COMPARTMENT	BAG TYPE	AVERAGE RELATIVE FLOW ± σ	
7	Criswell 442 10 oz. Teflon	0.99	± 0.04
10	Criswell 442 10 oz. Teflon	1.01	± 0.04
6	Menardi-Southern 10 oz. Teflon	1.09	± 0.07
9	Criswell 442 10 oz. Teflon Warp In	0.89	± 0.06
20	Criswell 449 14 oz. Tri-Treat Warp In	0.92	± 0.11
24	Globe-Albany Permaguard Nomex	1.33	± 0.07
26	Criswell 449 14 oz. COF	1.01	± 0.11
27	Criswell 449 14 oz. Tri-Treat	1.04	± 0.08
28	Criswell 449 14 oz. Tri-Treat	1.04	± 0.12
	6-inch Shaker Pulley Systems		
5	Criswell 442 10 oz. Teflon	1.26	± 0.07
8	Criswell 442 10 oz. Teflon	1.27	± 0.08

V. OPTIMIZING PERFORMANCE

A. Deflation

Harrington Station Unit 2 started up and operated until mid-June, 1979 without good deflation control. WFI recommended that deflation levels be at .5 inches w.g., which was very difficult to maintain manually. After rebagging the west baghouse, a control unit was installed by WFI, which gave operators the capability to change deflation from the control room, enhancing the ability to keep deflation at indicated levels.

During this period of time, Southwestern ran tests to see if bags were pancaking at 0.5 inches w.g. deflation pressure; results indicated that severe pancaking was taking place. By watching bags through observation ports in one compartment and lowering the deflation pressure drop until pancaking no longer occurred, 0.1 to 0.2 of an inch w.g. deflation pressure was determined to be an appropriate level to prevent pancaking.

Shortly thereafter, a deflation controller was installed and it has worked satisfactorily ever since. In the third year of study, Southwestern plans to conduct tests to see it simultaneous deflation and shake is advantageous. It is theorized that this may prevent any possible reentrainment of the dust.

B. Shake

According to the equations of Dennis ("Filtration Model For Coal Fly Ash With Glass Fabrics"[2]), the acceleration (a) of an element of filter fabric depends upon the amplitude of the shake and the frequency of the shake as follows:

$$a = Kf^2A = K' D_s{}^2A$$

where: A = shaker amplitude
f = shaker frequency
D_s = diameter of shaker pulley
K, K' = constants

The dependency of dust removal on the acceleration forces imparted to the fabric can be seen in Figure V-1. Dust removal is seen to increase linearly with the acceleration applied to the fabric during cleaning. The points represented in this figure are based on calculations done on data presented by Dennis for unnapped cotton bags.

To determine the effect of increased acceleration on cleaning, Southwestern decided to run some experimental tests with 6-inch shaker pulleys in place of the 4-inch diameter pulleys originally provided. Modifying the amplitude of the shaker to increase fabric acceleration during cleaning would have required fabrication of a special eccentric. Shaker frequency, however, is modified simply by changing the main drive pulley on the shaker motor shaft. On June 7, 1979, the following data was obtained at a 350 MW load:

Compartment	Pressure Drop	Pulley Size
17	10.3	4-inch, original bags
23	7.2	6-inch, Tri-Treat bags

The 3.1-inch w.g. pressure difference between the two compartments is due in part to the fabric difference as well as to the larger shaker pulley.

The shaker pulley on compartment 23 was changed to a 4-inch diameter on June 8, 1979, and the following data was collected on June 12, 1979:

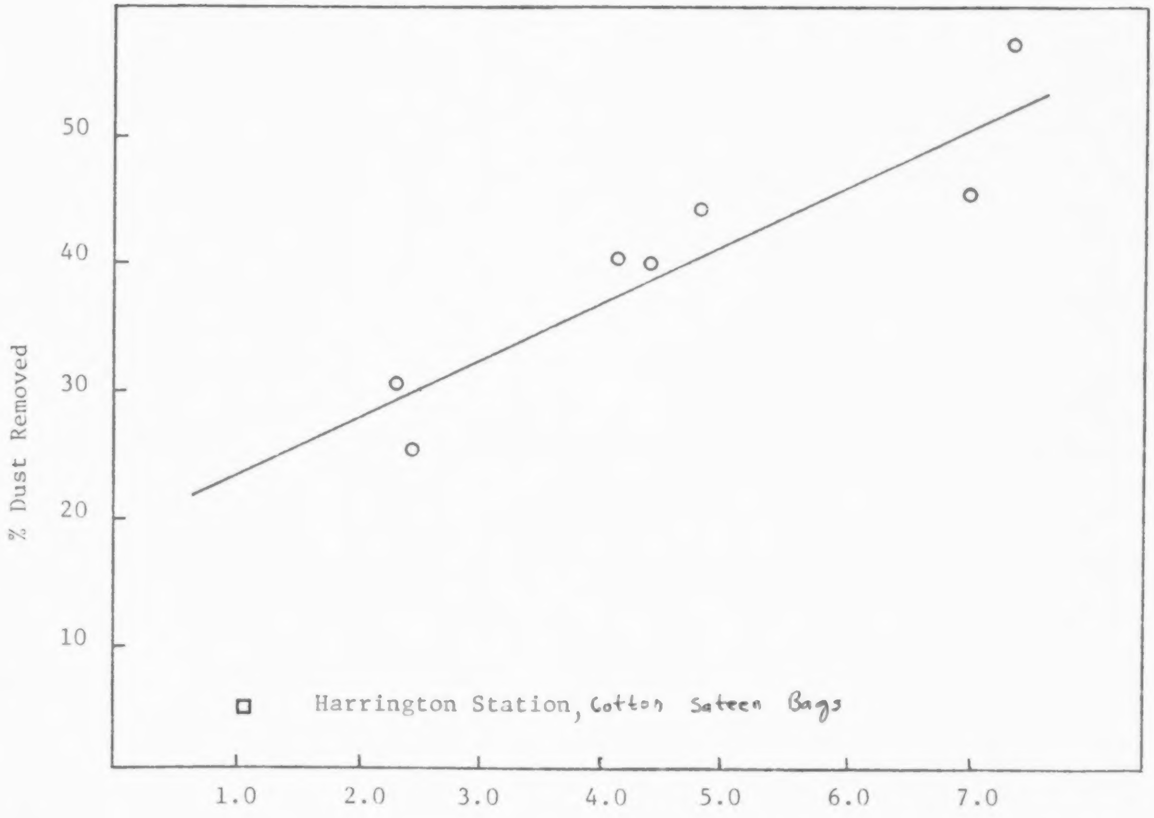

Figure V-1. Acceleration in G's.

Compartment	Pressure Drop	Pulley Size
17	8.6	4-inch
21	5.4	6-inch
23	7.2	4-inch

(Compartments 17 and 21 are shown for reference.)

Compartment 23 (with the 4-inch shaker pulley) has a lower pressure drop than compartment 17 (original fabric) by 1.4 inches w.g., due to the fabric difference alone. Compartment 21 and compartment 23 have exhibited almost indentical pressure drops with the 6-inch shaker pulleys. It can be inferred, then, that the 5.4-inch w.g. pressure drop shown for compartment 21 is at least in the ballpark of where compartment 23 would have performed with a 6-inch shaker pulley during this period. Therefore, it appears that the new fabric has lowered the pressure drop by 1.4 inches w.g. and also that increasing the shaker pulley diameter has lowered the pressure drop by an additional 1.8-inch w.g.

In Table V-I data is presented at various MW load levels showing the pressure drops for compartments 21 (Tri-Treat) and 23 (Teflon finished) as compared to compartment 17 with the original fabric.

In the lower half of Table V-I pressure drops are shown for 4-inch shaker pulleys on all compartments. It can be seen from the difference in pressure drops between compartments 21 and 17 that the fabric alone makes a difference of 0.5-1.50 inches w.g. Compartment 23, compared to the original fabric in compartment 17, shows a difference of 0.5-0.9 inches w.g.

When the 6-inch pulleys are installed on compartments 21 and 23, their pressure drops decrease even further when compared to compartment 17. Compartment 21 now has a pressure drop 2.50-3.70 inches w.g. lower than the original fabric in compartment 17. Compartment 23 (with the 6-inch shaker pulley) now has pressure drops 1.4-3.9 inches w.g. lower than the original fabric.

TABLE V-1. COMPARTMENT △P COMPARISONS

Date	Load	△P 17	△P 21	Difference Between 21 & 17	△P 23	Difference Between 23 & 17	Shaker Motor Pulley On 21 and 23
5/16	350	10.3	7.8	2.50	8.1	2.20	6 inch
5/4	330	10.4	7.8	2.60	8.2	2.20	6 inch
4/25	350	10.2	6.7	3.50	7.2	3.00	6 inch
4/24	350	10.6	6.9	3.70	6.7	3.90	6 inch
4/14	330	11.2	8.4	2.80	9.8	1.40	6 inch
3/10	300	7.0	6.0	1.0	6.3	0.70	4 inch
3/8	300	10.6	9.1	1.50	10.0	0.60	4 inch
3/5	350	9.7	8.3	1.40	8.8	0.90	4 inch
3/1	320	8.1	7.6	0.50	7.2	0.90	4 inch
2/27	350	9.8	8.3	1.50	8.5	1.30	4 inch
2/4	366	8.1	7.5	0.60	7.6	0.50	4 inch

TABLE V-2. SUMMARY OF COMPARTMENT △P COMPARISONS

@350 MW

Compartment	△P	Difference	Compartment	△P	Difference
17	9.75	0.45 (4 inch)	17	10.37	0.00 (4 inch)
21	8.30	1.45 (4 inch)	21	7.13	3.24 (6 inch)
23	8.65	1.10 (4 inch)	23	7.33	3.04 (6 inch)

In Table V-2, the difference between the original Criswell bags (17), the Teflon bags (21), and Tri-Treat bags (23) at high and low shake are summarized.

Table V-2 seems to indicate that the superior fabrics do help the pressure drop problem. It also appears that the increased shake on these fabrics doubled or tripled the decrease in pressure drop.

As a result of the experimental work with 6-inch diameter shaker pulleys, Southwestern decided to replace all of the 4-inch pulleys with 5.3-inch pulleys in all of the compartments.

C. Adjustment to Shaker Mechanisms

Increased shaker frequency (or rapidity) resulted in problems with the existing pillow blocks. The original structure simply had pillow blocks bolted to a plate without any lateral support and at least a quarter inch of shims was used to properly locate the pillow block. After installation of 6-inch pulleys on shaker mechanisms, the higher forces caused movement of pillow blocks and eventual damage to shaker mechanisms.

To remedy the situation, Southwestern designed a modified pillow block support structure (see Figure V-2). Since this modification was made in August, 1979, no failures have been observed due to loose pillow blocks.

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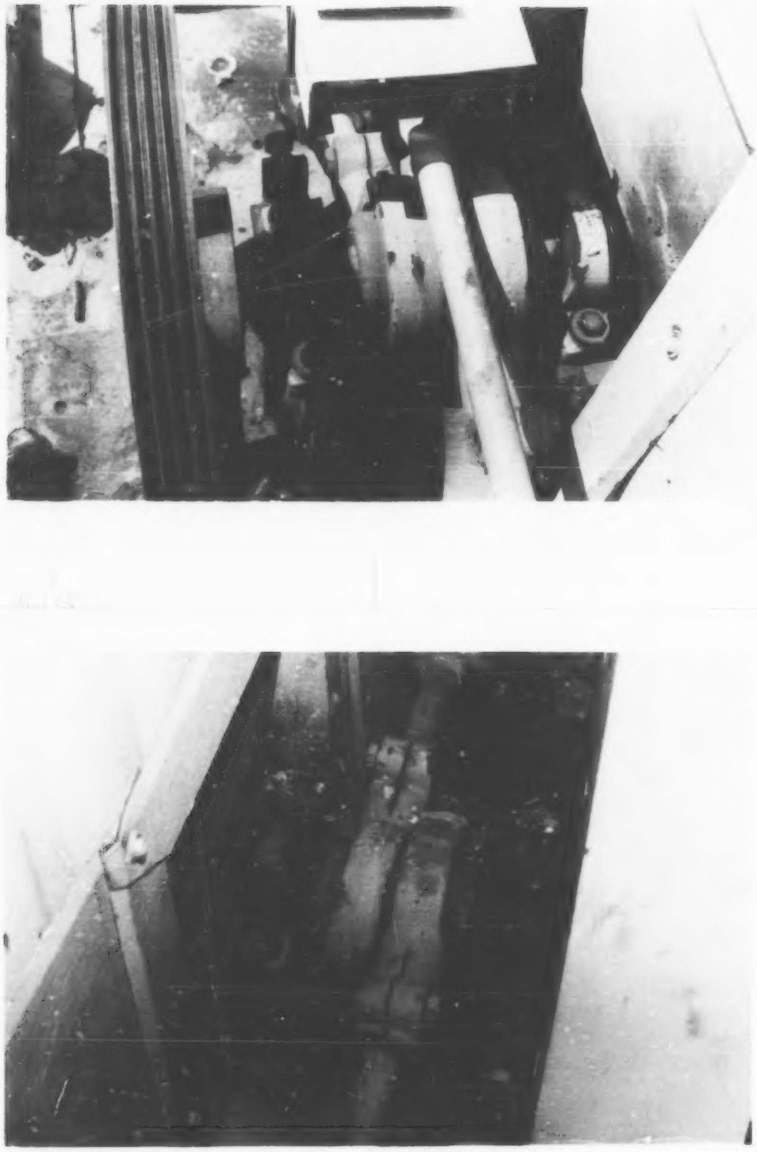

Figure V-2. Revised Pillow Block Supports.

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VI. OPERATING AND MAINTENANCE EXPERIENCE

A. Pressure Drop Performance

The Unit 2 fabric filter system was originally equipped with bags of fiberglass finished with a silicone/graphite mixture (W. W. Criswell style 445-04). The pressure drop characteristics of these bags are shown in Figures VI-1 and VI-2. A least squares curve fit of the east side baghouse data in Figure VI-1 is represented by the equation

$$\Delta P = 1.54 \ (A/C)^{1.44}$$

At an air-to-cloth ratio (A/C) of 3.4, the pressure drop is approximately 9 inches w.g. for the east side baghouse. This is significantly higher than the design pressure drop of 5 to 6 inches w.g.

Figure VI-2 shows that for many months both the east and west side baghouse pressure drops were comparable. However, in January, 1979, the west side baghouse began showing a steady increase in pressure drop, to more than 12 inches w.g. The east side pressure drop remained lower, probably because of modifications that included installation of test fabrics and changes to shaker assemblies.

In May, 1979, a decision was made to rebag the entire fabric filter system before the summer peak load. Not only was the pressure drop excessive, but the original bags had a high failure rate, and Southwestern could not risk curtailing generating capacity because of the fabric filter system.

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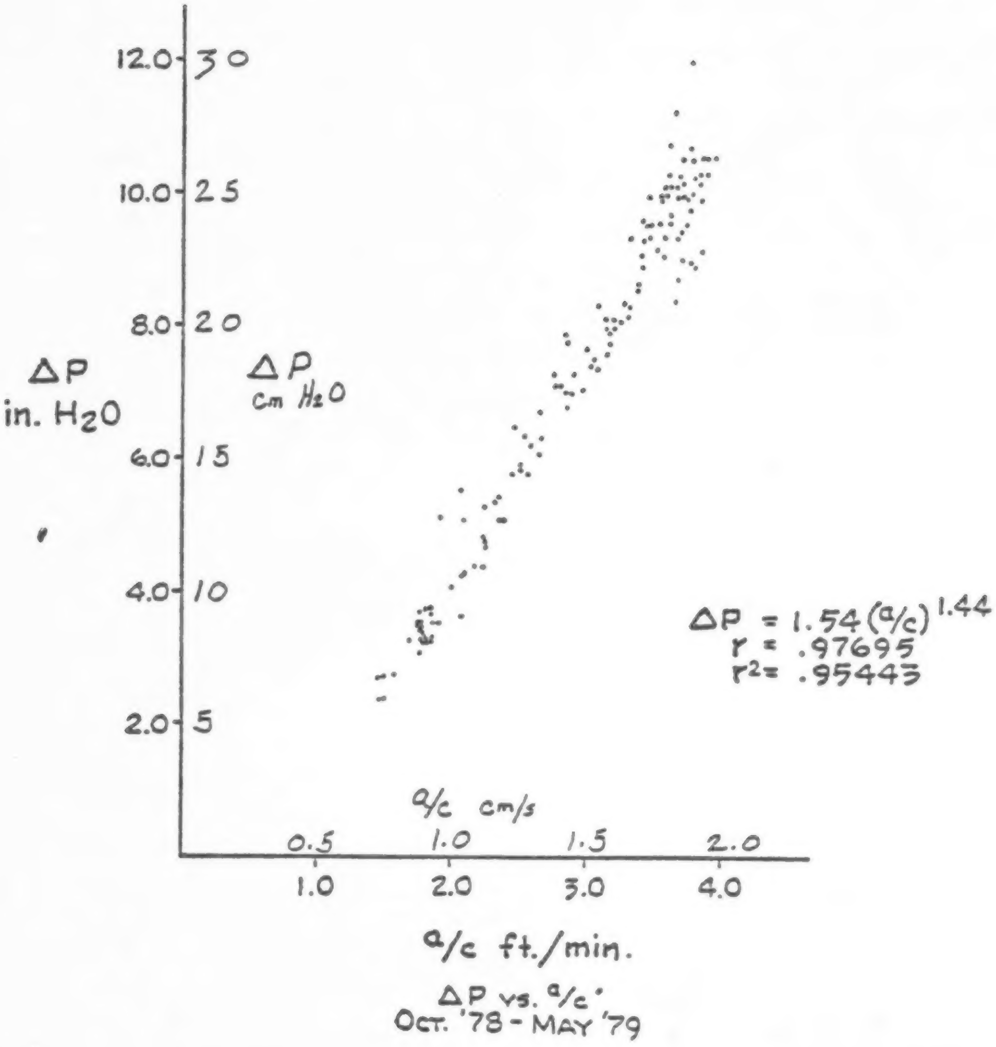

Figure VI-1. System Pressure Drop Correlations, Original Fabric.

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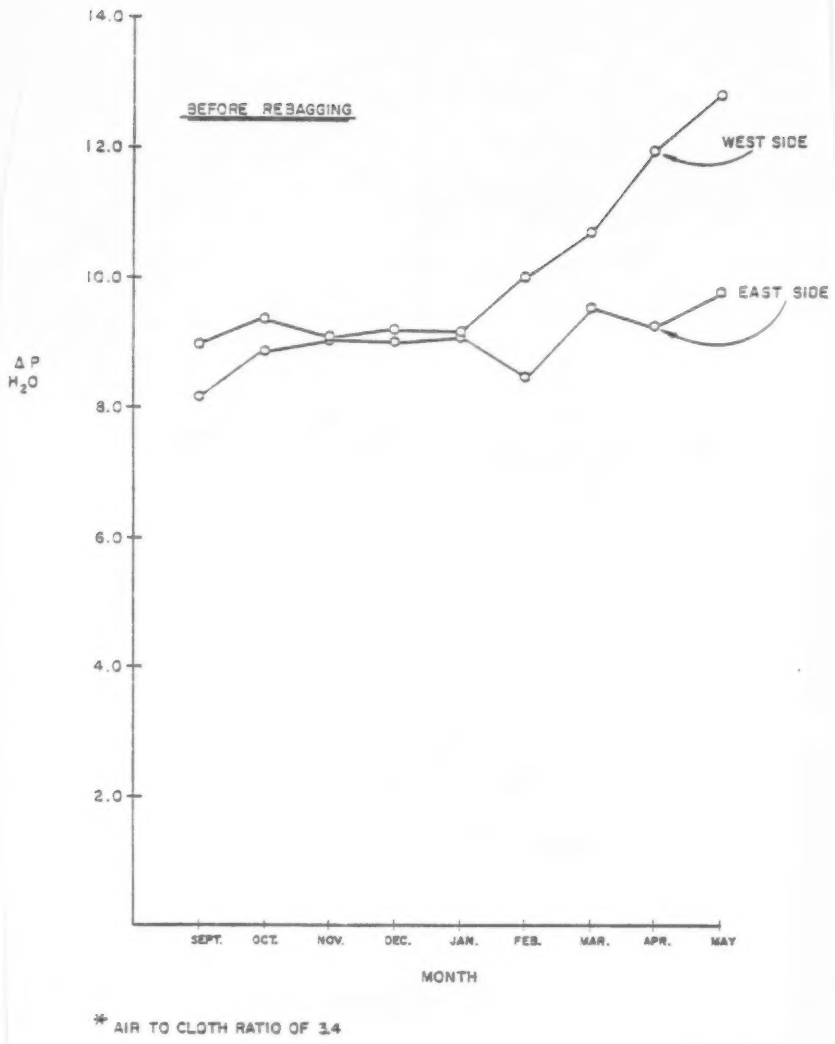

Figure VI-2. Monthly Full Load Pressure Drop, Original Fabric.

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Figure VI-2. Monthly Average ΔP Trend Before Rebagging

In June, 1979, the unit was rebagged as shown in Figure VI-3. Most of the compartments were equipped with fiberglass bags finished with 10 percent Teflon (Criswell style 442-57DC2) or another fiberglass bag coated with a proprietary finish (Criswell style 449-1580). Selection of these cloths was based on an evaluation of test compartments 21 and 23 which were rebagged in January, 1979. The manufacturer, finish type, weight, count, and permeability of the fabrics in current use are shown in Table IV-1.

Monthly average pressure drops for the first four months after rebagging are shown in Figure VI-4. It is significant that the pressure drops shown in Figure VI-4 after rebagging are substantially lower than those shown in Figure VI-2. Data in Figure VI-4 show that there was an increase in pressure drop during the first three months after rebagging for both the east and west sides. In early October, modifications to shaker speed may have helped reduce pressure drop. It is not yet possible to project pressure drop as a function of time. With both the original bags and the new bags, the west side pressure drop is somewhat higher than that in the east side. This difference may be partly due to some experimental bags in the east side compartments. There is no apparent difference in fly ash or flue gas properties for the two sides of the system.

B. Fabric Maintenance

As mentioned previously, severe pluggage in the west side of the baghouse and a high failure rate contributed to the decision to rebag the Unit 2 baghouse before the 1979 summer peak load. The availability of replacement bags, on short notice, required that half the baghouse be rebagged at a time. To remain within the emission limitations required by Federal and State regulatory agencies, the load on Harrington Station Unit 2 was reduced to 150 MW while one side of the baghouse

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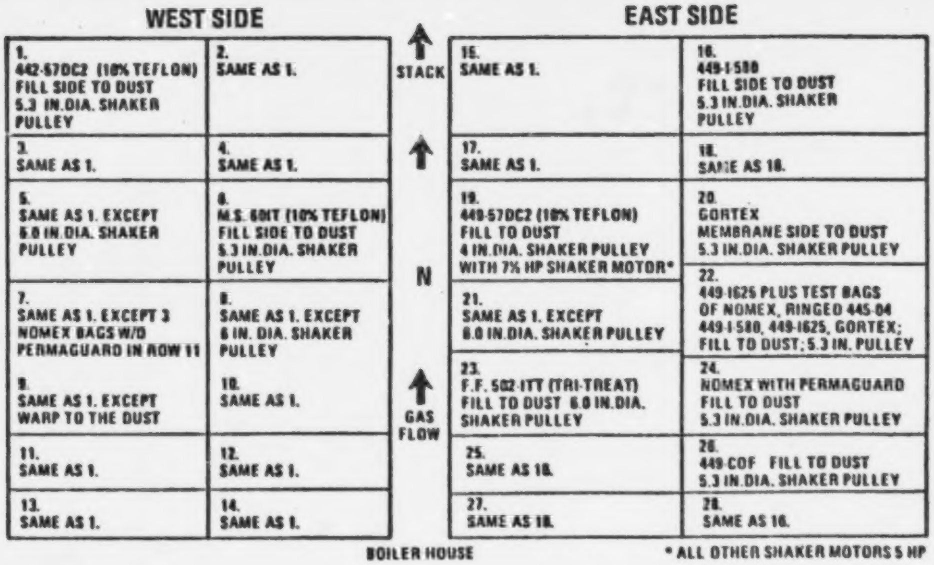

WEST SIDE

1. 442-57DC2 (10% TEFLON) FILL SIDE TO DUST 5.3 IN.DIA. SHAKER PULLEY	2. SAME AS 1.
3. SAME AS 1.	4. SAME AS 1.
5. SAME AS 1. EXCEPT 6.0 IN.DIA. SHAKER PULLEY	6. M.S. 601T (10% TEFLON) FILL SIDE TO DUST 5.3 IN.DIA. SHAKER PULLEY
7. SAME AS 1. EXCEPT 3 NOMEX BAGS W/O PERMAGUARD IN ROW 11	8. SAME AS 1. EXCEPT 6 IN. DIA. SHAKER PULLEY
9. SAME AS 1. EXCEPT WARP TO THE DUST	10. SAME AS 1.
11. SAME AS 1.	12. SAME AS 1.
13. SAME AS 1.	14. SAME AS 1.

EAST SIDE

15. SAME AS 1.	16. 449-I-580 FILL SIDE TO DUST 5.3 IN.DIA. SHAKER PULLEY
17. SAME AS 1.	18. SAME AS 16.
19. 449-57DC2 (10% TEFLON) FILL TO DUST 4 IN.DIA. SHAKER PULLEY WITH 7½ HP SHAKER MOTOR*	20. GORTEX MEMBRANE SIDE TO DUST 5.3 IN.DIA. SHAKER PULLEY
21. SAME AS 1. EXCEPT 6.0 IN.DIA. SHAKER PULLEY	22. 449-1625 PLUS TEST BAGS OF NOMEX, RINGED 445-04 449-I-580, 449-1625, GORTEX; FILL TO DUST; 5.3 IN. PULLEY
23. F.F. 502-ITT (TRI-TREAT) FILL TO DUST 6.0 IN.DIA. SHAKER PULLEY	24. NOMEX WITH PERMAGUARD FILL TO DUST 5.3 IN.DIA. SHAKER PULLEY
25. SAME AS 18.	26. 449-COF FILL TO DUST 5.3 IN.DIA. SHAKER PULLEY
27. SAME AS 18.	28. SAME AS 16.

* ALL OTHER SHAKER MOTORS 5 HP

Figure VI-3. Location of Fabrics by Compartment After Rebagging.

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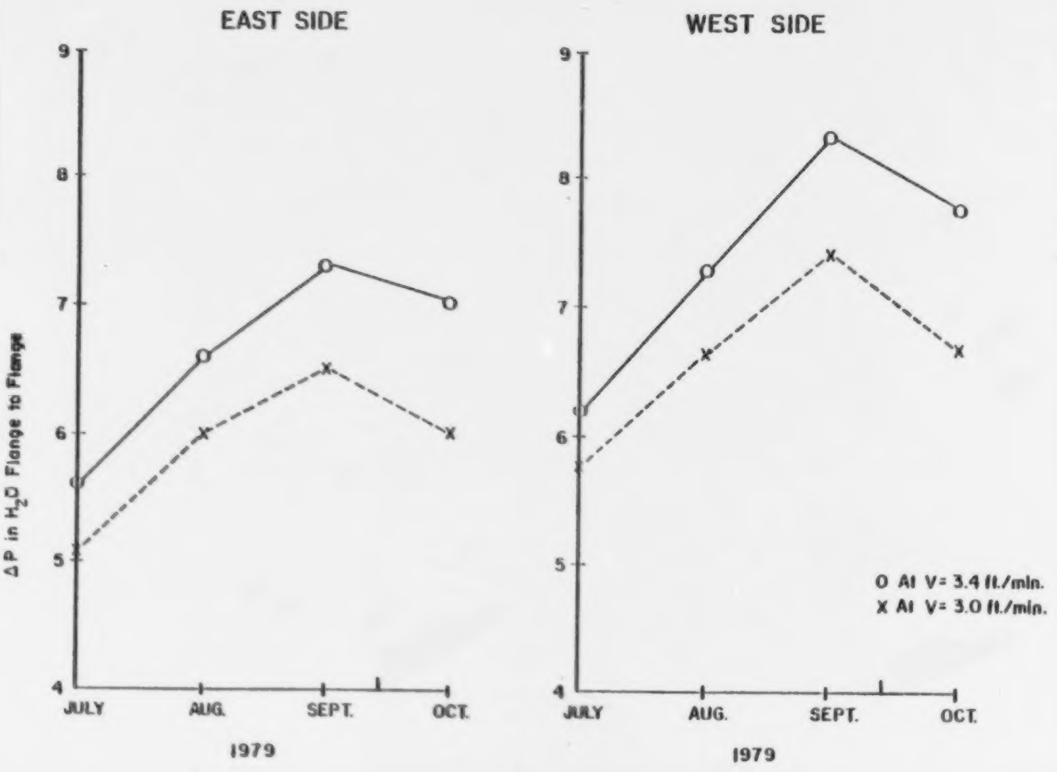

Figure VI-4 Monthly Full Load Pressure Drop, New Fabric.

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Figure VI 4, 5 Pressure Drop Since Rebagging was being rebagged. Because the west baghouse exhibited a higher pressure drop problem, it was rebagged first. The west baghouse was rebagged the week of June 16, 1979, and the east during the week of June 30, 1979. Approximately 3/4 of a manhour was required for each bag change.

Following rebagging, the start-up procedure was amended in the belief that the best way to condition a fabric is not at design air flow but at a lower flow. Southwestern felt that lower air flows would allow a more porous, permanent matrix to establish itself over the pores in the new fabric than would be possible at the very high flows Harrington Station's baghouse was designed for (air-to-cloth ratio = 3.4:1).

Start-up on the new fabric was accomplished by simply putting the rebagged unit on line at 150 MW and holding load until the baghouse had gone through the cleaning cycle several times. Cleaning at a ΔP of 5 inches w.g. required in excess of 36 hours to accomplish. The load was then increased by 50 MW a day until full load (350 MW) operation was achieved.

Periodic inspections of baghouse compartments are conducted by plant personnel. Parameters that are checked include general condition of bags, amount of ash in bag, pinhole failures, incipient blowouts, and general condition of compartment walls. Inspection findings are recorded on failure forms and included in monthly baghouse reports to the EPA.

During early months of operation, a great number of pinhole failures were observed at the cuff. Initially, these bags were replaced. However, since the failure affected such a small portion of the fabric, it seemed worthwhile to attempt repair of the bag. A Dow Corning silicone seal was applied to several of the pinholes and the fabric put back in service. After several months of continued operation, these repairs are still intact.

Southwestern feels the procedure for patching is an effective method of repair for pinhole failures in fabrics. Plans are being made to patch larger holes (2 to 6 inches in diameter) with used fabric held in place by silicone seal and Teflon thread. A future evaluation will be done to determine if this repair method is cost effective.

C. Repairs and Adjustments

1. Ventilation System: The design of the Harrington Unit 2 baghouse leaves the inside compartment and duct walls uninsulated in order to allow the compartments to be heated while the flue gas bypasses the baghouse. This design prevents condensation and corrosion problems during start-up. Single compartment inspections can be performed with the unit on line as long as it is not necessary for personnel to enter the upper level of the compartment. Since replacement of blown-out bags requires upper level entry where temperatures may be greater than 130°, a ventilation system became necessary for each compartment.

The ventilation system consists of a single fan on the ground level in duct work to and dampers for each of the 28 compartments. The system has been sized to deliver approximately 60,000 cfm of ambient air for compartment cooling.

2. Replacement of Hopper Heaters: Original hopper heaters in the Unit 2 FFS were made of silicone rubber, and applied with an adhesive to the hopper shell. During the first year of operation, 99 percent of these heaters failed. Beginning in September of 1979, they were replaced with a modular box-style heater.

3. Safety Features: During a Unit 2 outage in April of 1979, safety devices to prevent doors from blowing shut were placed on all compartment doors. Figure VI-5 shows a safety device in position. Seals on all compartment doors were also replaced on as as-needed basis during the second year of study.

D. Opacity

The Lear-Siegler RM41 Opacity Monitor appears to be a very stable and dependable instrument. To date the device has indicated very few adjustments and has given few maintenance problems. The sensitivity of the unit has allowed it to be used in precise pinpointing of failed bags by compartment.

In order to get good measurements, however, it is necessary to do a clear stack alignment while the unit is off line, i.e., during an overhaul. All attempts to do bench alignments have proven unsatisfactory.

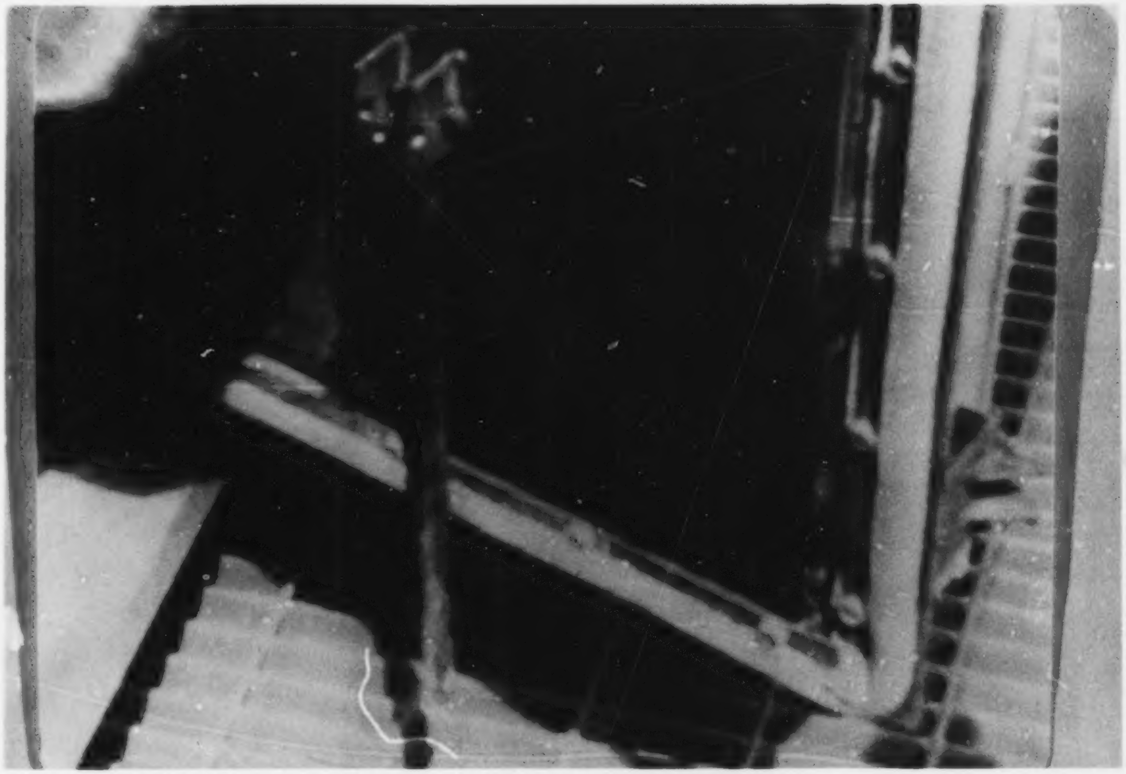

Figure VI-5. Safety Device.

VII. DATA ACQUISITION

Data from the following instrumentation is continuously collected by computer on an hourly basis and stored on a magnetic tape system.

Number of Instruments	Instrument	Location
Two	Annubar Flow Meter	Outlets
Five	Lear Siegler Model No. CM50 O_2 Meters	Two inlets, two outlets, one stack
Five	Lear Siegler SM800 SO_2/NO Monitors	Two inlets, two outlets, one stack
Four	IKOR Continuous Particulate Monitors	Two inlets, two outlets
Five	Chromel-Alumel Thermocouples	Two inlets, two outlets, one stack

Performance of the IKOR instrumentation has been so erratic and unstable that all attempts to make them function have been abandoned. Performance of the other instrumentation has been satisfactory.

The magnetic tape system originally installed, however, failed to operate and was eventually replaced. A large amount of data had been collected before the tape system was replaced and made to function. The only record available of this early data is daily print-outs of the Fabric Filter Summary Log (FFSL). Plans are being made to have this data keypunched during the third year of study so that a statistical evaluation can be made.

VIII. DATA ASSESSMENT

A major objective of the fabric filter study is to conduct a full and complete statistical examination of all data being collected by continuous sampling monitors. During the second year of study, this phase of the project was delayed due to the malfunction of the magnetic tape system. Statistical evaluation of SO_2, NO_x, O_2, and opacity data has not yet been performed. As soon as the data can be keypunched, it will be thoroughly analyzed by statistical means.

In order to carefully assess changes in pressure drop each month, a mathematical technique was derived to determine an average monthly full load pressure drop for each side of the baghouse. Pressure drop and air-to-cloth data that represented stable boiler operation were selected from the FFSL. Each month's data was then curve-fitted by the method of least squares to the equation

$$\Delta P = kV^n$$

In Table VIII-1, the results of these monthly correlations are shown for the original fabric. Once the value for k and n had been determined for each month's data, the monthly full-load pressure drop was calculated by inserting $V = 3.4$ into the equation.

Monthly full-load ΔP's were then plotted to detect trends in the data for both east and west baghouses. Values for the correlation coefficient are also shown in Table VIII-1.

TABLE VIII-1. Monthly Pressure Drop Correlation Parameters, Original Bags.

EAST

Month	k	n	r	r^2	ΔP at 3.0 %	ΔP at 3.4 %
Sept.	1.53	1.36	.973	.948	6.82	8.08
Oct.	1.56	1.41	.998	.995	7.34	8.76
Nov.	1.50	1.46	.996	.991	7.46	8.95
Dec.	1.32	1.57	.992	.984	7.41	9.02
Jan.	1.34	1.55	.999	.998	7.41	8.93
Feb.	1.26	1.54	.985	.971	6.84	8.30
Mar.	1.45	1.52	.996	.991	7.70	9.32
Apr.	1.57	1.43	.983	.966	7.55	9.03
May	2.22	1.19	.945	.894	8.21	9.52

WEST

Month	k	n	r	r^2	ΔP at 3.0 %	ΔP at 3.4 %
Sept.	1.58	1.41	.965	.933	7.44	8.87
Oct.	1.70	1.38	.989	.978	7.74	9.20
Nov.	1.58	1.43	.989	.978	7.60	9.09
Dec.	1.48	1.48	.983	.966	7.52	9.05
Jan.	1.60	1.41	.991	.982	7.53	8.98
Feb.	2.13	1.25	.989	.978	8.41	9.83
Mar.	2.30	1.24	.991	.982	8.98	10.49
Apr.	3.70	0.94	.954	.909	10.39	11.69
May	3.10	1.14	.969	.941	10.85	12.51

Values in every case are greater than 0.94, which indicates a very high degree of correlation with this single variable (air-to-cloth).

It is of interest to note that the values of n tended to be constant, averaging 1.4. Exceptions to this occurred February through May in the west baghouse during a period when fabric was undergoing severe pluggage. This can be seen in monthly full-load pressure drop values. Therefore, the values of the k parameter are the ones that seem to most strongly reflect variations in monthly performance.

The unit was rebagged in the summer of 1979. Table VIII-2 also shows the curve fit parameters for the first three months of operation of the new cloth. Monthly full-load pressure drops are considerably lower than with original fabric. The values of the parameter n for both the east and west baghouses appear to be steadily increasing, an indication that they have not yet stabilized.

Southwestern will continue to observe these parameters and assess their relationship to baghouse performance.

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TABLE VIII-2. Curve Fit Parameters, New Fabric.

Month	k	n	r	△P 3.4	△P 3.0
WEST					
July	2.8396	0.6320	0.8849	6.15	5.69
Aug.	2.947	0.7342	0.9583	7.24	6.60
Sept.	2.705	0.9138	0.9795	8.28	7.38
EAST					
July	2.396	0.6914	0.7367	5.58	5.12
Aug.	2.549	0.7788	0.9686	6.61	6.00
Sept.	2.447	0.8928	0.9841	7.3	6.52

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TABLE VIII-2 CURVE FIT PARAMETERS

IX. SPECIAL STUDY AREAS

A. Corrosion Coupon Test Program

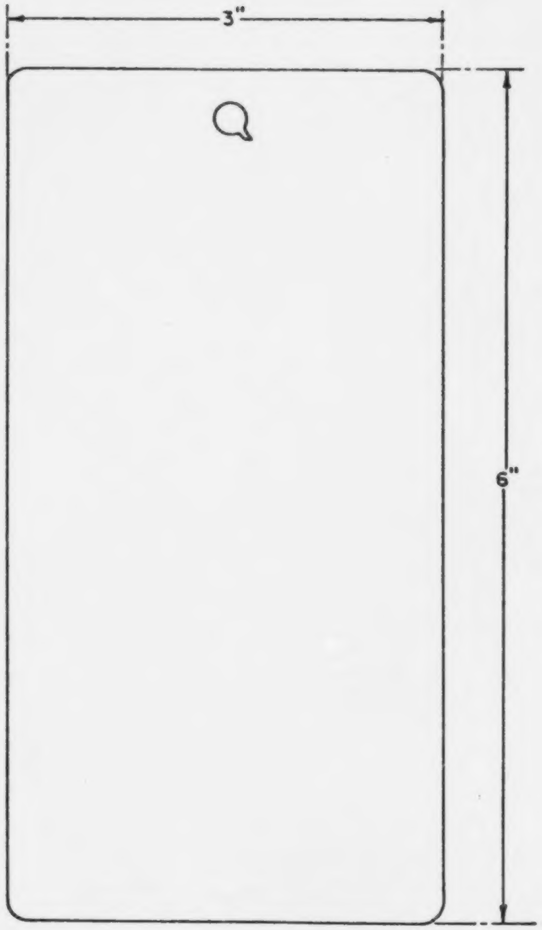
Southwestern has developed and implemented procedures to determine and monitor the relative corrosion rates of mild steel experienced in the Harrington Unit 2 baghouse. By using coupons made from representative metals and following specified procedures for installation, removal, and weight measurement, corrosivity rates can be effectively analyzed. Figures IX-1 and IX-2 show corrosion test coupon size, weight and thickness, and corrosion coupon assembly.

On February 28, 1978, 41 coupons were prepared by the System Lab. Each coupon was numbered to correspond to the same baghouse compartment number (1 through 28 for compartments, 29 through 36 for inlet and outlet ducts, and 37 through 41 for spares). Coupons were then installed in their respective locations on June 22, 1978, prior to closing up the baghouse for operation. (See Appendix D for related drawings.) General instructions for coupon preparation, cleaning, drying, and evaluation are also included in Appendix D.

On December 1, 1978, every other compartment coupon was removed. Results of this first analyses are shown in Table IX-1, which indicate the corrosion rate at this point is minimal.

B. Electrostatics

It has been speculated that electrostatic effects may be a contributing factor to certain bag cleaning problems at Harrington Station. During testing done by Acurex Corporation



Area ____________ 36 Sq. Inches
Average Weight _______ 74.5 Grams
Average Thickness ______ 0.0315"

Figure IX-1. Corrosion Test Coupon.

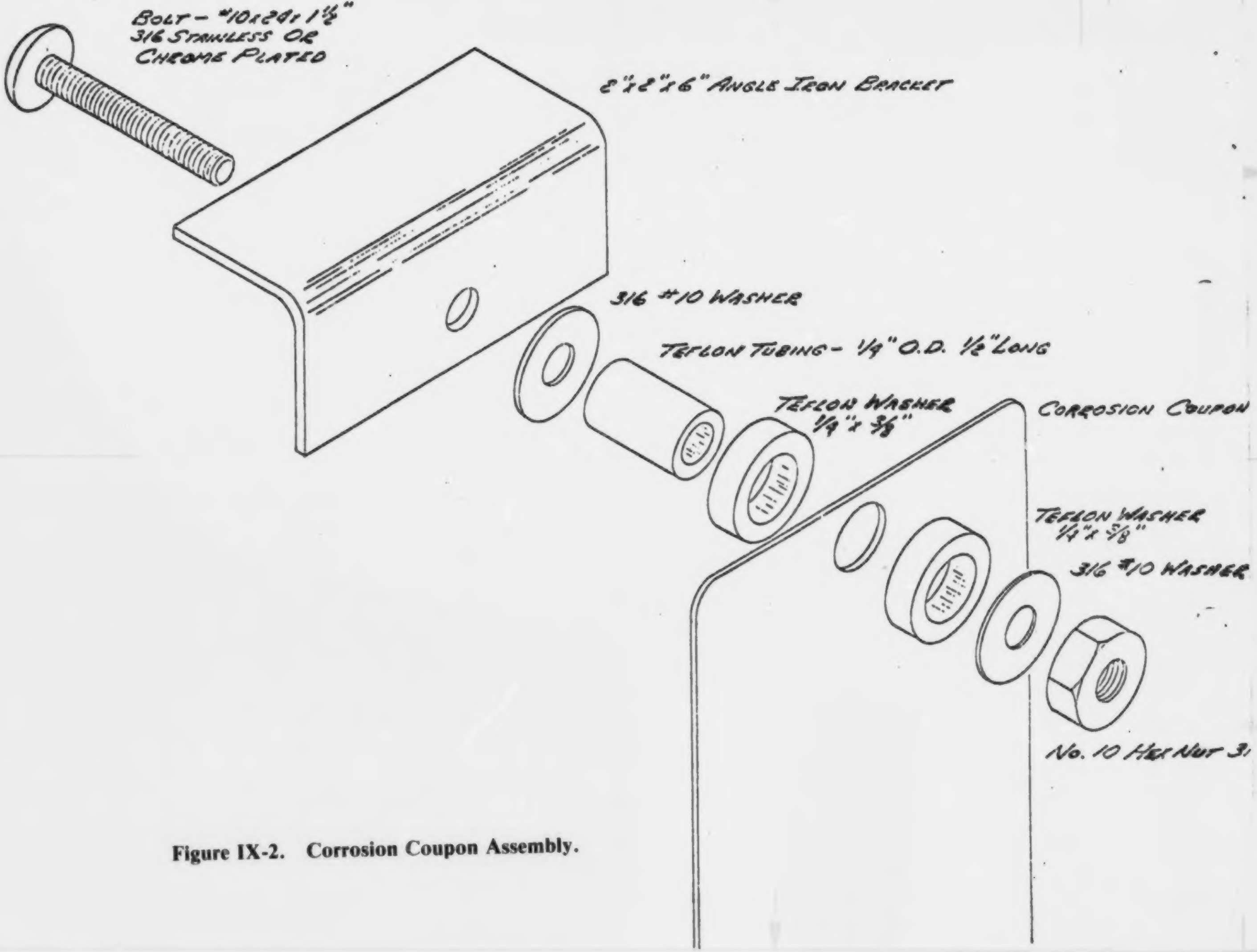

BOLT - #10x24x1½"
316 STAINLESS OR
CHROME PLATED
2"x2"x6" ANGLE IRON BRACKET
316 #10 WASHER
TEFLON TUBING - ¼" O.D. ½" LONG
TEFLON WASHER
¼" x ⅝"
CORROSION COUPON
TEFLON WASHER
¼" x ⅝"
316 #10 WASHER
No. 10 HEX NUT 3

Figure IX-2. Corrosion Coupon Assembly.

TABLE IX-1. CORROSION COUPON ANALYSES RESULTS

Coupon & Compartment No.	Original Wt. G.	Final Wt. G.	Loss In Wt. G.	Corrected Wt. Loss G.	Date Installed	Date Removed	Days Exposed	Mills Per Year Loss	Pitting Depth
1.	72.1150	72.0904	0.0246	0.0175	6-22-78	12-01-78	162	0.008	None
4.	71.4497	71.4318	0.0179	0.0108	6-22-78	12-01-78	162	0.005	None
5.	71.3295	71.3155	0.0140	0.0069	6-22-78	12-01-78	162	0.003	None
8.	71.5762	71.5569	0.0193	0.0122	6-22-78	12-01-78	162	0.006	None
9.	71.1310	71.1133	0.0177	0.0106	6-22-78	12-01-78	162	0.005	None
12.	71.1820	71.1686	0.0134	0.0063	6-22-78	12-01-78	162	0.003	None
13.	71.5155	71.4610	0.0545	0.0474	6-22-78	12-01-78	162	0.023	None
15.	71.7500	71.7350	0.0150	0.0079	6-22-78	12-01-78	162	0.004	None
18.	74.3495	74.3364	0.0131	0.0060	6-22-78	12-01-78	162	0.003	None
19.	73.1115	73.0770	0.0345	0.0274	6-22-78	12-01-78	162	0.013	None
22.	71.4255	71.4085	0.0170	0.0099	6-22-78	12-01-78	162	0.005	None
23.	71.2358	71.2179	0.0179	0.0108	6-22-78	12-01-78	162	0.005	None
26.	72.4751	72.4659	0.0092	0.0021	6-22-78	12-01-78	162	0.001	None
27.	75.9499	75.9396	0.0103	0.0032	6-22-78	12-01-78	162	0.002	None
2.	71.4471	71.4203	0.0268	0.0197	6-22-78	03-20-79	271	0.006	None
3.	72.4578	72.4416	0.0162	0.0091	6-22-78	03-20-79	271	0.003	None
7.	71.4606	71.3975	0.0631	0.0560	6-22-78	03-20-79	271	0.016	None
10.	71.3176	71.2893	0.0283	0.0212	6-22-78	03-20-79	271	0.006	None
11.	71.3980	71.3870	0.0110	0.0039	6-22-78	03-20-79	271	0.001	None
14.	71.7493	71.7100	0.0393	0.0322	6-22-78	03-20-79	271	0.009	None
16.	76.3133	76.2571	0.0562	0.0491	6-22-78	03-20-79	271	0.014	None
17.	74.1110	74.0848	0.0262	0.0191	6-22-78	03-20-79	271	0.005	None
20.	73.9455	73.9360	0.0095	0.0024	6-22-78	03-20-79	271	0.001	None
21.	71.1887	71.1643	0.0244	0.0173	6-22-78	03-20-79	271	0.005	None
24.	75.8967	75.8688	0.0279	0.0208	6-22-78	03-20-79	271	0.006	None
25.	75.8130	75.7767	0.0363	0.0292	6-22-78	03-20-79	271	0.008	None
29.	75.6703	75.5187	0.1516	0.1445	6-22-78	03-20-79	271	0.041	None
30.	76.3859	76.3714	0.0145	0.0074	6-22-78	03-20-79	271	0.002	None
31.	68.1900	68.1124	0.0776	0.0705	6-22-78	03-20-79	271	0.020	None
34.	78.3320	78.3099	0.0221	0.0150	6-22-78	03-20-79	271	0.004	None
36.	76.9453	76.7690	0.1763	0.1692	6-22-78	03-20-79	271	0.048	None

in their mobile baghouse study, an attempt was made to measure electrostatic voltage levels present on the original silicone/graphite bags in the mobile baghouse. The methodology was the same as that employed by R. P. Donovan and M. B. Ranade, Research Triangle Institute (RTI), on the main baghouse in March, 1979. (Their report is attached as Appendix E.)

A cage voltage measurement was made by attaching a Type 430 stainless steel screen (0.0075-inch wire, 24 mesh) cage to the bottom of the middle bag in the Acurex baghouse. The cage was attached to the bag by sewing it to the bag cuff at the cage top, middle, and bottom points in such a way that no penetration of the filtering surface of the bag was required. The cage was 25.4cm high and was constructed such that the diameter was only slightly larger than that of the bag. A Teflon-shielded cable from the cage was passed through the adjacent glass window jamb and coupled to an electrometer immediately adjacent to the baghouse compartment.

The profile of cage voltage measurements is shown in Figure IX-3 over two typical cleaning/filtration cycles. A detailed analysis or hypothesis of the resultant effect on bag pressure drop was beyond the scope of the Acurex study. However, it appears that sufficient charge levels were shown to exist to be a potential contributing factor to pressure drop problems and to indicate the need for further definition, clarification, and evaluation. Therefore, future plans have been made by the EPA to initiate a joint program with RTI to conclusively study electrostatics.

C. Quality Assurance

An important part of the Southwestern/EPA project is to utilize a consultant to develop a formal Quality Assurance (QA) program which will ensure the quality of data from all testing. The total program must be encompassed by formal written quality control procedures. The QA program shall be

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BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD. BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA: OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
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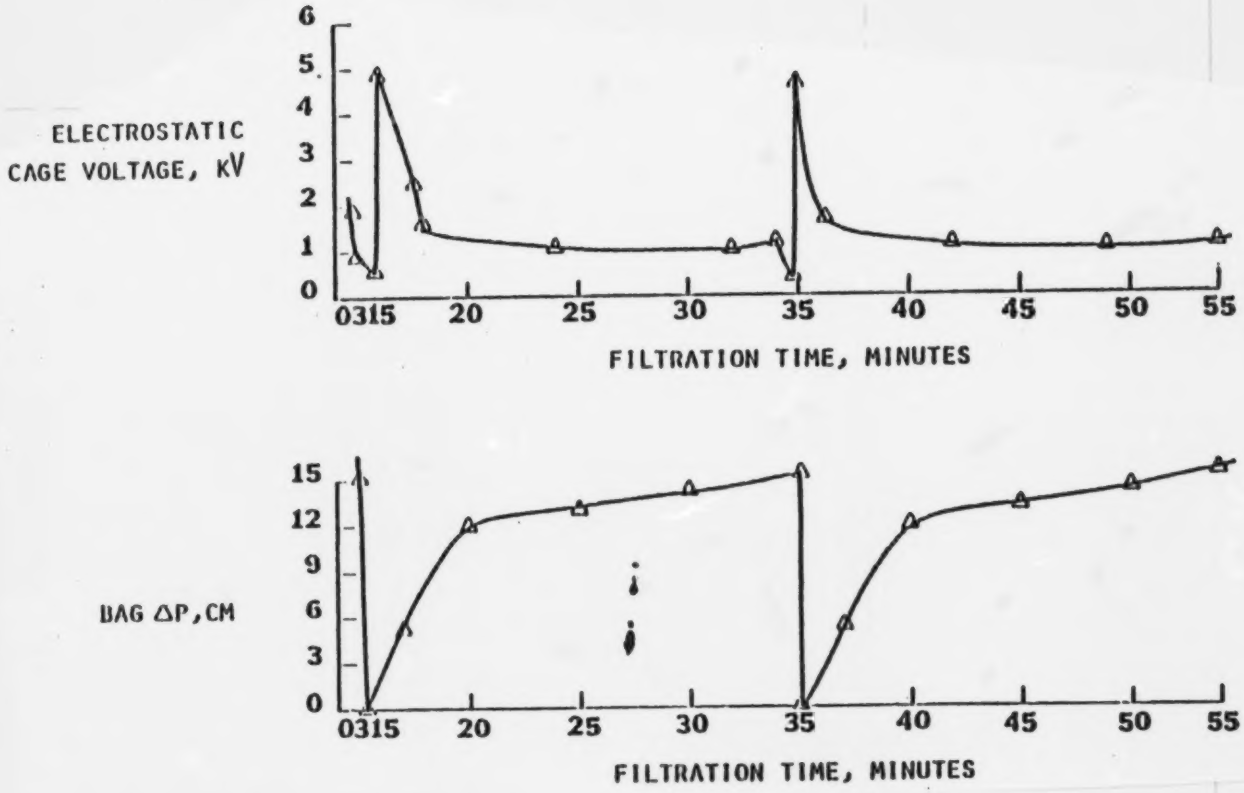

Figure IX-3. Electrostatic Cage Voltage Profile For Two Typical Cleaning Cycles.

implemented by Southwestern personnel and an outside firm which specializes in sampling and analyses of emissions from a steam generator.

The following areas are considered to be essential elements of a QA program for a demonstration project. These areas shall be thoroughly analyzed and appropriate procedures written for each.

1. Facilities and equipment
2. Configuration control
3. Personnel training
4. Documentation control
5. Control charts
6. In-process quality control
7. Procurement and inventory procedures
8. Preventative maintenance
9. Reliability
10. Data validation
11. Feedback and corrective action
12. Calibration procedures

On March 9, 1979, Southwestern project personnel met with representatives of Research Triangle Institute (RTI), an EPA contractor specializing in quality control. The purpose of the meeting was to hear RTI's advice on organizing a QA program for the Harrington Station baghouse study.

RTI recommended certain checks and procedures, and specified what a QA plan should consist of; they also developed a configuration (or check list) for Southwestern to use in setting up its QA program. With that information Southwestern developed a Request for Proposal (RFP) and solicited bids from consultants for preparing the QA document.

RFP's were sent to the following companies on April 10, 1979:

1. Entropy Environmentalist
2. Ecology Audit
3. Southwest Research Institute
4. Southern Research Institute
5. Radian Corporation
6. Mullins Environmental Testing Co., Inc.

Either negative or no response at all was received from these companies, except Entropy Environmentalist. Due to the decision to rebag the baghouse in June, 1979, the testing program was delayed, allowing more time for consultants to respond to the RFP. In addition, two more companies were asked to submit proposals:

1. Engineering-Science
2. Environmental Research & Technology, Inc.

The Technical Proposals from the two companies that responded were adequate to fulfill the requirements of the QA plan. Based upon the information supplied in the Technical Proposals and an evaluation of the Cost Proposals, Environmental Research and Technology, Inc. of Concord, Massachusetts, was selected to develop the QA program for the fabric filter study.

Personnel from ERT will be on site for the second special test to be conducted by Southwestern in October, 1979. A draft QA document is expected for review in January, 1980.

REFERENCES

1. Ladd, K. L., Faulkner, G. R., and Kunka, S. L., "Fabric Filter System : First Annual Report," EPA-600/7-79-183, August 1979.
2. Dennis, Richard, Cass, R.W., Cooper, O.W., Hall, R.R., Hampl, Vladimir, Klemm, H.A., Langley, J.E., and Stern, R.W., GCA Corporation. "Filtration Model for Coal Fly Ash with Glass Fabrics," EPA-600/7-77-084 (NTIS No. PB 276 489), August 1977.

APPENDIX A. FIRST SPECIAL TEST - RAW FIELD DATA

WTM # 11AJ9

FEB 8 1979

WET TEST METER CALIBRATION

FORM IV

Run #1

Date 2/2/79

Calibrated by S. Thurman & L. Fajardo

Weight of Water added to Flask 45,951g gm

Temperature of water in flask 71°F °C

Density of water at this temperature (ρ) 0.99780g/ml

Wet Test Meter Reading Finish 0691.876

Wet Test Meter Reading Start - 0690.256

Wet Test Meter Reading Difference (WTMRD) 1.620 ft³

$$\frac{1}{\rho} \quad \frac{\text{ft}^3}{28{,}316\ \text{ml}} \quad \frac{x\ \text{gm}}{1} = 1.63\ \text{ft}^3\ \text{standard}$$

$$\text{Wet Test Meter Correction Factor} = \frac{\text{standard}}{\text{WTMRD}} = \frac{1.626}{1.620} = 1.004$$

$$\frac{1\ \text{ml}}{0.99780\text{g}} \times \frac{1\ \text{ft}^3}{28{,}316\ \text{ml}} \times 45{,}951\text{g} = 1.63\ \text{ft}$$

Avg: 1.003

WTM #11.59

Run #2

WET TEST METER CALIBRATION

FORM IV

Date 2/2/79

Calibrated by L. Fajardo, S. Thurman

Weight of Water added to Flask 45,950 gm

Temperature of water in flask 71° F = 22 °C

Density of water at this temperature (ρ) 0.99780 g/ml

Wet Test Meter Reading Finish 0693.497

Wet Test Meter Reading Start 0691.876

Wet Test Meter Reading Difference (WTMRD) 1.621 ft³

$$\frac{1}{\rho} \quad \frac{\text{ft}^3}{28,316\ \text{ml}} \quad \frac{x \quad \text{gm}}{1} = 1.626\ \text{ft}^3\ \text{standard}$$

$$\text{Wet Test Meter Correction Factor} = \frac{\text{standard}}{\text{WTMRD}} = 1.003$$

WTM # 11H39

Run #3

WET TEST METER CALIBRATION

FORM IV

Date 2/2/79

Calibrated by Fajardo, Thurman

Weight of Water added to Flask 45,994 gm

Temperature of water in flask 21 °C

Density of water at this temperature (p) 0.99802

Wet Test Meter Reading Finish 0695.121

Wet Test Meter Reading Start - 0693.497

Wet Test Meter Reading Difference (WTMRD) 1.624 ft³

$$\frac{1}{\rho} \quad \frac{ft^3}{28,316\ ml} \quad \frac{x\ \ gm}{1} = 1.628\ ft^3 \text{ standard}$$

$$\text{Wet Test Meter Correction Factor} = \frac{\text{standard}}{\text{WTMRD}} = 1.002$$

FEB 6 1979

D. Gas Meter Calibration Form I

By Wet Test Meter

Date: 2/5/79

Control Terminal: C171

Purpose: Post Test Calibration

Calibrated: S. THURMAN

Wet Test Meter, Final (WTMF) 0705.333 cf

Wet Test Meter, Initial (WTMI) 0695.[illegible] cf

WTD = (WTMF-WTMI) 9.456 cf

Calibration Factor For Wet Test Meter (WF) 1.003

Date Of Last Calibration For Wet Test Meter 2/3/79

Temperatures	Ambient	Inlet	Outlet
Initial	74	93	75
Final	74	101	77
Sum	2) 148	194	1[illegible]2
		+	194
Average Ambient Temp (T_a)	74 F	4)	346 F

Average Dry Gas Meter Temp (T_m) 86.5 F

Dry Gas Reading, Final (DGF) 731.200 cf

Dry Gas Reading, Initial (DGI) 719.700 cf

DGF-DGI 11.[illegible] cf

Dry Gas Meter Factor (DF) = WTD*WF*(460+Tm) / (DGF-DGI)*(460 + Ta) = .977

Avg of 3 Runs: 0.973

RUN#2

D. Gas Meter Calibration Form 1

By Wet Test Meter

Date: 3/5/79

Control Terminal: 8171

Purpose: Post Test Calibration

Calibrated: S. Thomas

Wet Test Meter, Final (WTMF) 715.741 cf

Wet Test Meter, Initial (WTMI) 706.360 cf

WTD = (WTMF-WTMI) 9.381 cf

Calibration Factor For Wet Test Meter (WF) 1.003

Date Of Last Calibration For Wet Test Meter 3/2/79

Temperatures	Ambient	Inlet	Outlet
Initial	73	93	77
Final	73	95	77
Sum	2) 146	188	154
			+ 188
Average Ambient Temp (T_a)	73 F		4) 342 F

Average Dry Gas Meter Temp (T_m) 85.5 F

Dry Gas Reading, Final (DGF) 741.012 cf

Dry Gas Reading, Initial (DGI) 731.011 cf

DGF-DGI 10.001 cf

Dry Gas Meter Factor (DF) $= \frac{WTD*WF*(460+Tm)}{(DGF-DGI)*(460+Ta)}$ = 0.963

Reproduced from best available copy.

D.. Gas Meter Calibration Form 1

By Wet Test Meter

Run #3

Date: 2/5/79

Control Terminal: C-171

Purpose: Post Test Calibration

Calibrated: Leo Fajardo

Wet Test Meter, Final (WTMF) 0725.812 cf

Wet Test Meter, Initial (WTMI) 0716.250 cf

WTD = (WTMF-WTMI) 9.562 cf

Calibration Factor For Wet Test Meter (WF) 1.003

Date Of Last Calibration For Wet Test Meter 2/2/79

Temperatures	Ambient	Inlet	Outlet
Initial	73	89	75
Final	70	98	77
Sum	2) 143	187	152
			+ 187
Average Ambient Temp (T_a)	71.5 F		4) 339 F

Average Dry Gas Meter Temp (T_m) 84.75 F

Dry Gas Reading, Final (DGF) 251.649 cf

Dry Gas Reading, Initial (DGI) 241.649 cf

DGF-DGI 10.000 cf

Dry Gas Meter Factor (DF) $= \frac{WTD * WF * (460+Tm)}{(DGF-DGI) * (460 + Ta)}$ = 0.983

12-11-78

Time	Pressure	Temp.
8:00	26.85	74°
9:00	26.85	72°
10:00	26.86	70°
11:00	26.87	70°
12:00	26.86	71°
1:00	26.83	70°
2:00	26.79	70°
3:00	26.76	70°
4:00	26.77	71°
5:00	26.72	70°

12-12-78

Time	Pressure	Temp.
8:00	26.59	70°
9:00	26.57	68°
10:00	26.50	72°
11:00	26.58	68°
12:00	26.57	70°
1:00	26.53	69°
2:00	26.52	70°
3:00	26.50	68°
4:00	26.51	74°
5:00	26.52	69°

12-13-78

Time	Pressure	Temp.
8:00	26.98	70°
9:00	27.00	70°
10:00	27.04	71°
11:00	27.03	72°
12:00	27.02	70°
1:00	27.02	70°
2:00	27.01	70°
3:00	27.01	70°
4:00	26.97	69°
5:00	26.96	70°

12-14-78

Time	Pressure	Temp.
8:00	26.67	72°
9:00	26.64	71°
10:00	26.61	70°
11:00	26.60	74°
12:00	26.57	71°
1:00	26.52	73°
2:00	26.49	77°

12-15-78

Time	Pressure	Temp.
10:00	26.37	73°
11:00	26.36	72°
12:00	26.36	73°
1:00		
2:00	26.32	70°
3:00	26.32	71°
4:00		

Stack

NOZZLE AND K DETERMINATION

File H#2 Before
Part - Prelim
Data

Step 1. Calculate the following nozzle determination constant:

$$C = \left(\begin{array}{l}\text{Preliminary}\\\text{Velocity}\\\text{ft/sec}\end{array}\right) \times \left(\frac{60\ \text{sec}}{\text{min}}\right) \times \left(\begin{array}{l}\text{Dry Gas}\\\text{Fraction}\end{array}\right) \times \left(\frac{\text{Stk. Press. "Hg}}{29.92\ \text{"Hg}}\right) \times \left(\frac{530\ ^\circ\text{R}}{\text{Stk. Temp. }^\circ\text{R}}\right)$$

$$C = (82.7) \times (60) \times (.904) \times \left(\frac{26.37}{29.92\text{"Hg}}\right) \times \left(\frac{530}{819}\right) = \underline{2558.4}\ \text{ft/min}$$

Step 2. Calculate the desired Nozzle Area from the desired flow rate: (See sampling manual for guidelines on desired flow rate)

$$\begin{array}{l}\text{Desired}\\\text{Nozzle Area}\end{array} = \left(\frac{\begin{array}{l}\text{Desired flow rate}\\\text{at STP, ft}^3\text{/min}\end{array}}{\text{C, from above, ft/min}}\right) = \left(\underline{\qquad\qquad}\right) = \underline{\qquad\qquad}\ \text{ft}^2$$

Step 3. Choose appropriate nozzle from those available. Noz. # Selected ________, Area of nozzle selected __________ ft²
This nozzle may be changed for subsequent samples. Always indicate the area used on each field data sheet. Each sample point is sampled for an equal amount of time. Total sample time is the product of the number of points & the time per point.

Step 4. Calculate the flow rate at standard conditions for this nozzle.

$$\begin{array}{l}\text{Flow Rate for}\\\text{Nozzle Selected}\end{array} = \left(\begin{array}{c}\text{Area of Nozzle}\\\text{Selected}\end{array}\right) \times \left(\begin{array}{c}\text{Constant}\\\text{C, above}\end{array}\right) = (1.4913 \times 10^{-4}) \times (2558.4) = \underline{.38}\ \text{SCFM}$$

Check the total sample volume. Max & Min. sample volume is discussed in the Sampling Manual.

$$\begin{array}{l}\text{Total}\\\text{Vol.}\end{array} = (\text{SCFM}) \times \left[\begin{array}{l}\text{Total}\\\text{time,}\\\text{min.}\end{array}\right] = (\quad) \times (\quad = \underline{\qquad}\ \text{ft}^3\ \text{@STP Dry}$$

Step 5. Calculate ΔH: $\Delta H = a\,(\text{SCFM})^b = (3.042)\,(.38)^{[2.209]} = \underline{.44}\ \text{"H}_2\text{O}$
The orifice curve constants, a and b, are posted on the front of each console.

Step 6. Calculate ΔP: $\Delta P = (\text{Aver. } \sqrt{\Delta p})^2 = (1.18)^2 = \underline{1.40}\ \text{"H}_2\text{O}$
Average $\sqrt{\Delta p}$ is from the preliminary velocity calculations.

Step 7. Calculate K: $K = \left(\frac{\Delta H}{\Delta P}\right) = (\underline{\qquad}) = \underline{\qquad\qquad}$.
K will be used to determine each ΔH, i.e. $\Delta H_n = \Delta P_n \times K \times \left(\frac{Tm^\circ R}{530}\right)^b$
K may be changed for subsequent samples. Always indicate the K factor used on each data sheet.

FIELD CHECK OF PERCENT ISOKINETIC – #2 Baghouse Test / Particulate #1 12-8

The following field check should be performed after the first sample and may be performed after subsequent samples if changes were made. None of the results from this page are used as input into the final data reduction.

1. Calculate nozzle volume at stack conditions (NVSC) given the following items obtained during the sample:

   a. Corrected dry gas volume. DGV 37.574 ft^3 ✓
   b. Aver. Stack Temp., TS 815.2 °R ✓
   c. Aver. Meter Temp., TM 510.1 °R ✓
   d. Dry Gas Fraction, BDG .911 ✓

[illegible] – 2" H_2O

$$NVSC = \frac{DGV \times \frac{(TS)}{(TM)}}{BDG} = \frac{(37.574) \times \frac{(815.2)}{(510.12)}}{(.911)} = 69.45\ ft^3$$

2. Calculate the average corrected stack velocity (V). First, sum the square roots of the Δp's obtained during the sample and divide by N, the number of Δp's, to obtain the average square root of Δp:

$$\text{Aver. } \sqrt{\Delta p} = \frac{\Sigma \sqrt{\Delta p}}{N} = \frac{(14.34)}{(12)} = 1.195\ \text{in.}^{\frac{1}{2}}$$ ✓

$$V = 85.48 \times PTCF \sqrt{\frac{TS}{\text{Mole Wt.} \times \text{Stack Press}}} \times \text{Aver. } \sqrt{\Delta p}$$

$$V = 85.48 \times (.794) \sqrt{\frac{(815.2)}{(29.27) \times (26.64)}} \times (1.195) = 82.91\ \text{ft/sec}$$ ✓

Preliminary molecular weight may be used unless significant changes occured in moisture fraction. Preliminary stack pressure may be used.

3. Calculate percent isokinetic given:

   a. Nozzle volume, NVSC 69.45 ft^3
   b. Nozzle area, AN 1.4913×10^{-4} ft^2
   c. Sample Time, TIM 5760 seconds
   d. Aver. Corrected Velocity, V 82.91 ft/sec

$$\%\ Iso. = \frac{NVSC \times 100\%}{AN \times TIM \times V} \quad \frac{(69.45) \times 100\%}{(1.4913 \times 10^{-4}) \times (5760) \times (82.91)} = 97.5\ \%$$

FIELD CHECK ON MOISTURE FRACTION

Pilot # 2 [illegible]
Run #1 12/13/78

Corrected sample Vol. (V)

(net vol) x (DGMCF) = 39.574 ft³ ✓

Avg. meter temp., TM = Avg. meter temp. °F + 460 = 510.1 °R

Total imp. wt. gain, MWC 76.15 grams H_2O ✓

Pressure at meter, PM 26.70 inches Hg ✓

$$\text{Moisture Fraction} = \frac{(\text{MWC}) \times 1.339 \ \frac{\text{liters}}{\text{gm } H_2O}}{\left[(\text{MWC}) \times 1.399 \ \frac{\text{liters}}{\text{gm } H_2O}\right] + \left[\frac{(V) \times (PM)}{(TM)} \times 501.7 \ \frac{\text{liters } ^\circ R}{\text{ft}^3 \text{ in.Hg}}\right]}$$

$$\text{Moisture Fraction} = \frac{(76.15) \times 1.339}{\left[(76.15) \times 1.339\right] + \left[\frac{(39.574) \times (26.70) \times 501.7}{(510.12)}\right]} = \_\_\_\_$$

Dry Gas Fraction = 1 - (moisture fraction) = 1 - (.089) = .911

FIELD CHECK OF MOLECULAR WEIGHT

(To be used when substantial changes have occured in the moisture fraction)

	Molecular Weights		Moisture Fraction		Partial Mol. Wt.
H_2O	18	X	.089	=	1.60

		Orsat Fraction	Dry Gas Fraction		
CO_2	44	X .134	.911 (see above)	=	5.37
O_2	32	X .062		=	1.81
CO	28	X 0		=	
N_2	28	X .808		=	20.610

Molecular Weight of Stack Gas 29.28
(Sum of partial molecular weights)

DATE 12/13/78

SIGNATURE Olon C Plumb

ELD CHECK OF PERCENT ISOKINETIC

Part #3 12-15-78

The following field check should be performed after the first sample and may be performed after subsequent samples if changes were made. None of the results from this page are used as input into the final data reduction.

1. Calculate nozzle volume at stack conditions (NVSC) given the following items obtained during the sample:

   a. Corrected dry gas volume. DGV 40.224 ft^3 ✓OP
   b. Aver. Stack Temp., TS 810.3 °R ✓OP
   c. Aver. Meter Temp., TM 512.8 °R ✓OP
   d. Dry Gas Fraction, BDG .908

$$NVSC = \frac{DGV \times \frac{(TS)}{(TM)}}{BDG} = \frac{(40.224) \times \frac{(810.3)}{(512.8)}}{(.908)} = \overset{69.18}{\cancel{70.00}}\ ft^3$$

2. Calculate the average corrected stack velocity (V). First, sum the square roots of the Δp's obtained during the sample and divide by N, the number of Δp's, to obtain the average square root of Δp:

$$\text{Aver. } \sqrt{\Delta p} = \frac{\Sigma \sqrt{\Delta p}}{N} = \frac{(14.20)}{(12)} = 1.183 \text{ in.}^{\frac{1}{2}}$$ ✓OP

$$V = 85.48 \times PTCF \sqrt{\frac{TS}{\text{Mole Wt.} \times \text{Stack Press}}} \times \text{Aver. } \sqrt{\Delta p}$$

$$V = 85.48 \times (.794) \sqrt{\frac{(810.3)}{(29.\cancel{37}\,37) \times (26.\cancel{22})}} \times (1.183) = 82.34 \text{ ft/sec}$$ ✓OP

Preliminary molecular weight may be used unless significant changes occured in moisture fraction. Preliminary stack pressure may be used.

3. Calculate percent isokinetic given:

   a. Nozzle volume, NVSC ~~70.00~~ 69.18 ft^3
   b. Nozzle area, AN 1.4913×10^{-4} ft^2
   c. Sample Time, TIM 5760 seconds
   d. Aver. Corrected Velocity, V 82.31 ft/sec

$$\% \text{ Iso.} = \frac{NVSC \times 100\%}{AN \times TIM \times V} \quad \frac{(\overset{69.98}{\cancel{70.00}}) \times 100\%}{(1.4913_{\times 10^{-4}}) \times (5760) \times (82.31)} = \frac{\cancel{99.01}}{95.25}\ \%$$ ✓OP

FIELD CHECK ON MOISTURE FRACTION

[illegible]
Port #2 12-14-78

Corrected sample Vol. (V)

(net vol) x (DGMCF) = 40.224 ft³ ✓OP

Avg. meter temp., TM = Avg. meter temp. °F + 460 = 512.8 °R ✓OP

Total imp. wt. gain, MWC 78.1 grams H_2O ✓OP

Pressure at meter, PM 26.29 inches Hg

$$\text{Moisture Fraction} = \frac{(\text{MWC}) \times 1.339\ \frac{\text{liters}}{\text{gm } H_2O}}{\left[(\text{MWC}) \times 1.399\ \frac{\text{liters}}{\text{gm } H_2O}\right] + \left[\frac{(V) \times (PM)}{(TM)} \times 501.7\ \frac{\text{liters } ^\circ R}{\text{ft}^3 \text{ in.Hg}}\right]}$$

$$\text{Moisture Fraction} = \frac{(\ 78.1\ ) \times 1.339}{[(\ 78.1\ ) \times 1.339] + \left[\frac{(\ 40.224\ ) \times (\ 26.29\ ) \times 501.7}{(\ 512.8\ )}\right]} = .092$$

Dry Gas Fraction = 1 - (moisture fraction) = 1 - (.092) = .908

FIELD CHECK OF MOLECULAR WEIGHT

(To be used when substantial changes have occured in the moisture fraction)

	Molecular Weights		Orsat Fraction	Moisture Fraction / Dry Gas Fraction		Partial Mol. Wt.
H_2O	18	x		[.092]	=	1.656
CO_2	44	X	.145 ✓OP	[.908 (see above)]	=	5.793
O_2	32	X	.058 ✓OP		=	1.743
CO	28	X	0		=	0
N_2	28	X	.798		=	20.212

Molecular Weight of Stack Gas .... ~~29.41~~ 29.31
(Sum of partial molecular weights)

DATE____________________

SIGNATURE____________________

ILD CHECK OF PERCENT ISOKINETIC

Stack
Run #3 12/15/7

The following field check should be performed after the first sample and may be performed after subsequent samples if changes were made. None of the results from this page are used as input into the final data reduction.

1. Calculate nozzle volume at stack conditions (NVSC) given the following items obtained during the sample:

   a. Corrected dry gas volume. DGV 40.187 ft³ ✓OP
   b. Aver. Stack Temp., TS 820.3 °R ✓OP
   c. Aver. Meter Temp., TM 515.7 °R ✓OP
   d. Dry Gas Fraction, BDG ~~.898~~ .904 ✓OP

$$NVSC = \frac{DGV \times \frac{(TS)}{(TM)}}{BDG} = \frac{(40.187) \times \frac{(820.3)}{(515.7)}}{(\cancel{.898}\ .904)} = \frac{\cancel{71.18}\ 70.69}{} \text{ ft}^3$$

2. Calculate the average corrected stack velocity (V). First, sum the square roots of the Δp's obtained during the sample and divide by N, the number of Δp's, to obtain the average square root of Δp:

$$\text{Aver. } \sqrt{\Delta p} = \frac{\Sigma \sqrt{\Delta p}}{N} = \frac{(14.352)}{(\cancel{14.2}\ 12)} = 1.196 \text{ in.}^{\frac{1}{2}}$$ ✓OP

$$V = 85.48 \times PTCF \sqrt{\frac{TS}{\text{Mole Wt.} \times \text{Stack Press}}} \times \text{Aver. } \sqrt{\Delta p}$$

$$V = 85.48 \times (.794) \sqrt{\frac{(820.3)}{(29.21) \times (26.00)}} \times (1.196) = 84.\cancel{52}\,37 \text{ ft/sec}$$ ✓ OP

Preliminary molecular weight may be used unless significant changes occured in moisture fraction. Preliminary stack pressure may be used.

3. Calculate percent isokinetic given:

   a. Nozzle volume, NVSC ~~71.18~~ 70.69 ft³
   b. Nozzle area, AN 1.4913 X 10⁻⁴
   c. Sample Time, TIM 5760 seconds
   d. Aver. Corrected Velocity, V 84.~~52~~37 ft/sec

$$\% \text{ Iso.} = \frac{NVSC \times 100\%}{AN \times TIM \times V} \quad \frac{(70.69) \times 100\%}{(1.4913 \times 10^{-4}) \times (5760) \times (84.37)} = \frac{\cancel{98.84}}{97.5}\ \%$$ ✓OP

FIELD CHECK OF MOISTURE FRACTION

File H#2
Port

Stack
Run #3 12/15/78

Corrected sample Vol. (V)

(net vol) x (DGMCF) = 40.187 ft^3

Avg. meter temp., TM = Avg. meter temp. °F + 460 = 515.7 °R

Total imp. wt. gain, MWC ~~67.8~~ 80.5 grams H_2O

Pressure at meter, PM 26.06 inches Hg

$$\text{Moisture Fraction} = \frac{(MWC) \times 1.339 \frac{\text{liters}}{\text{gm } H_2O}}{\left[(MWC) \times 1.399 \frac{\text{liters}}{\text{gm } H_2O}\right] + \left[\frac{(V) \times (PM)}{(TM)} \times 501.7 \frac{\text{liters } ^\circ R}{\text{ft}^3 \text{ in.Hg}}\right]}$$

$$\text{Moisture Fraction} = \frac{(\cancel{67.8}\ \cancel{96.05}\ 80.5) \times 1.339}{\left[(\cancel{67.8}\ \cancel{96.05}\ 80.5) \times 1.339\right] + \left[\frac{(40.187) \times (26.06) \times 501.7}{(515.7)}\right]} = \cancel{.102}\ .09$$

Dry Gas Fraction = 1 - (moisture fraction) = 1 - (~~.102~~ .096) = ~~.898~~ .904

FIELD CHECK OF MOLECULAR WEIGHT

(To be used when substantial changes have occured in the moisture fraction)

	Molecular Weights		Moisture Fraction		Partial Mol. Wt.
H_2O	18	X	[~~.102~~ .096]	=	~~1.836~~ 1.728

		Orsat Fraction	Dry Gas Fraction		
CO_2	44 X	.136		=	~~5.337~~ 5.410
O_2	32 X	.054	[~~.898~~ .904 (see above)]	=	~~[illegible]~~ 1.562
CO	28 X	0		=	
N_2	28 X	.814		=	~~[illegible]~~ 20.104

Molecular Weight of Stack Gas .... 29.20 ✓ DP
(Sum of partial molecular weights)

DATE 12/15/78

SIGNATURE Olen Fluck

PARTICULATE TEST CALCULATIONS Stack TACB Method

RUN #	M_n mg	V_m cu ft	V_{mstd} cu ft	P_{bar} in Hg	ΔH in H_2O	T_m °R	B_{wo} Frac H_2O	V_s ft/sec	O_2 % ~~A~~ ~~ft2~~	P_s in Hg	T_s °R	C_s lb/dscf	C_s gr/scf
1	171.9	39.574	36.58	26.70	.45	570.1	.089	82.91	6.2	26.64	815.2	1.1564×10^{-5}	.081
2	145.7	40.224	36.42	26.29	.45	572.8	.092	82.34	5.8	26.22	810.3	8.8181×10^{-6}	.062
3	157.1	40.187	35.87	26.06	.46	575.7	.096	84.[illegible]	5.4	26.00	820.3	9.[illegible]	[illegible]

	F Factor Q_s= ~~10^7 dscf/hr~~	Part. Emission Rate lb/hr	Total Gas Flow Rate CFM	Coal Flow Rate TPH	Btu Value Coal Btu/lb	Heat Rate 10^6Btu/hr	Load MW	% Opacity	% Isokinetic	Particulate Emission Rate lb/10^6 Btu
1	9758	[illegible]	0	204.7	8525	3490.1	357.5	3.5	97.5	.160
2	9779	413	0	205.8	8437	3472.7	357.2	2.8	99.0	.111
3	9728	441	0	204.0	8517	3474.9	357.7	2.8	97.5	.1[illegible]1

PARTICULATE TEST CALCULATIONS

Stack EPA Method

RUN #	M_n mg	V_m cu ft	V_{mstd} cu ft	P_{bar} in Hg	ΔH in H_2O	T_m °R	B_{wo} Frac H_2O	V_s ft/sec	O_2 %	P_s in Hg	T_s °R	C_s lb/dscf	C_s gr/sc
1	126.7	37.594	36.58 ✓	26.70	.45	510.1	.089	82.91	6.2	26.64	815.2	7.6348×10^{-6} ✓	.05
2	117.0	40.224	36.42 ✓	26.27	.45	512.8	.072	82.34	5.8	26.22	810.3	7.20[illegible]×10^{-6} ✓	.0[illegible]
3.	76.4	40.187	35.97	26.05	.46	515.7	.096	84.37	5.4	26.00	820.3	4.6825×10^{-6}	.0[illegible]

	F factor	~~Q_s dscf/hr~~	Part. Emission Rate lb/hr	Total Gas Flow Rate CFM	Coal Flow Rate TPH	Btu Value Coal Btu/lb	Heat Rate 10^6Btu/hr	Load MW	% Opacity	% Isokinetic	Particulate Emission Rate lb/10^6 Btu
1	9758	[illegible]	370	0	204.7	8525	3490.1	359.5	3.5	97.5	.1[illegible]6 ✓
2	9777	[illegible]	337	0	205.8	8437	3472.7	357.2	2.8	99.0	.[illegible]17 ✓
3	9728	[illegible]	212	0	204.0	[illegible]	3474.9	357.7	2.8	97.5	.061 ✓

APPENDIX B. WFI SPECIAL FABRIC STUDY

SPS/WFI FABRIC FILTER
HARRINGTON UNIT 2
ANALYSIS OF FLYASH PARTICLE SIZE
AND OTHER DATA ON DUSTUBES
FROM THE CENTER AND CORNER
OF COMPARTMENT 13
PROJECT NO. 7110-03
REPORT NO. 1

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APPROVED BY
A.E. POTTER

ISSUED 9-20-79

SUMMARY AND CONCLUSIONS

A study was carried out to resolve several questions regarding the particle size of the flyash at Harrington Unit 2 and the distribution of the size fractions to bags at different locations within a compartment and within individual bags.

Although the original plan, proposed at a meeting in Amarillo, Texas, on May 15, 1979, called for taking two bags out of each of two compartments, it was only possible to sample compartment 13.

A bag from the center of the compartment and one from the front corner were tied off into three approximately equal sections just before the compartment was due to clean. The bags were then removed and shipped to Mishawaka where each was cut into three sections which were weighed and sampled.

Moisture, helium pycnometer density, and particle size by A-B Sonic Sifter and Bahco Micro Particle Classifier were determined on the six samples of flyash.

Scanning electron micrographs were made of samples of the flyash, dust cake, and cloth.

Samples of the cloth were sent to W.W. Criswell to have its general condition evaluated.

Five samples of the flyash had a mass median diameter close to their average of 5.7 micrometers. The sixth which was from the bottom section of the corner bag had a mass median diameter of 9.4 micrometers. It was expected that the corner location, opposite the inlet, would get the heaviest load of the coarsest dust. The concentration of the coarser dust at the bottom of the bag is explained by the fact that the vertical gas velocity in the bag decreases as gas filters through its sides.

The electron micrographs were typical of pulverized coal flyash with few distinctions among them other than the 230X picture of ash from the bottom of 1-1 showing a few more coarse particles than the others. Micrographs of the cloth did not show broken fibers other than those produced in the bulking operation.

Results of the tests carried out by Criswell were typical of glass cloth after having been in service a short time. The strength drops sharply and then remains at a substantially constant value until the bag nears the end of its life. The permeability is typical of cloth from an operating collector.

DESCRIPTION AND DISCUSSION

At a meeting held in Amarillo, Texas, on May 15, 1979 which was attended by both Southwestern Public Service and Wheelabrator-Frye personnel a decision was made to carry out a test on the particle size of the flyash from Harrington Unit 2. The objective of this test, as originally planned, was to determine the particle size of the flyash from Harrington Unit 2 and the variation in particle size as a function of the height within a bag, the location of the bag within a compartment, and the position of the compartment along the inlet plenum. When the bags were removed on June 6, 1979 it was only possible to sample compartment 13 so the effect of position on the plenum could not be investigated.

Compartment 13 was isolated just before its cleaning cycle was due to start. Two bags, 1-1, in the front left corner, and 6-9, in the center of the compartment, were tied off at the top and bottom and at points as far up from the bottom and as far down from the top as could be reached. The two bags were then removed from the compartment and shipped to the WFI R&D laboratory in Mishawaka, Indiana.

When the bags were received in Mishawaka they were measured and each was cut into three sections at the tie points and each section put into a plastic bag and then weighed. The bottom of the bags had an identification tag and the cut intermediate section was tagged to identify its bottom end. After the bags with dust were weighed, the bag sections were carefully lifted out of the plastic bags so that the loose dust could slide out of them and were transferred to clean plastic bags. The six bags containing the loose dust and those containing the bag sections were then weighed. Weights and lengths are given in Table I. There is an indication that the dust cake decreases with height in the bag.

Several hundred grams of each of the dust samples was removed for laboratory examination. The samples were dried at 110 C prior to density and particle size determinations. Density was determined using a Micromeritics Helium Pycnometer. Particle size determination was by A-B Sonic Sifter in the mesh size range and by Bahco Micro Particle Classifier in the sub-sieve range. The latter instrument was calibrated against ASME Standard Sample DB-5 before the samples were run. Table II shows the results of these tests and Figures 1-6 are the size distribution curves for the samples.

Samples of the cloth and dust were taken to W.C. Mc Crone Assoc. in Chicago for scanning electron microscopy examination. This work was performed by John Brown. The micrographs of the dust samples appeared similar to those of flyash in the "Particle Atlas." At low magnification the sample from the bottom of bag 1-1 appeared to have

TABLE I

COMPARTMENT 13 BAG 1/1

	LENGTH (in)	WEIGHT (lb)			WEIGHT PER FOOT		
		BAG + DUST	DUST	BAG	BAG + DUST	DUST	BAG
Bottom	115	16-1/2	11-1/2	6	1.7	1.2	0.6
Middle	81-1/2	15	11	4	2.2	1.6	0.6
Top	164-3/4	11	4	7-1/2	0.8	0.3	0.6
Middle + Top	246-1/4	26	15	11-1/2	1.3	0.7	0.6

NOTE: There was a problem tying off the top section and a lot of the dust dropped into the middle hence the combined figures.

COMPARTMENT 13 BAG 6/9

	LENGTH (in)	WEIGHT (lb)			WEIGHT PER FOOT		
		BAG + DUST	DUST	BAG	BAG + DUST	DUST	BAG
Bottom	100	13	8	5	1.6	1.0	0.6
Middle	105-1/2	12	8	4-1/2	1.4	0.9	0.5
Top	160-1/4	16-1/2	9-1/2	7 +	1.2	0.7	0.5

TABLE II

SAMPLE	MOISTURE %	DENSITY	MESH SIZE (%) -100	-140	-200	MASS MEDIAN DIAMETER MICROMETERS
1/1 Bottom	0.12	2.71	95.5	93.9	87.6	9.4
1/1 Middle	0.13	2.69	98.5	96.1	90.4	5.7
1/1 Top	0.12	2.73	98.5	95.3	88.6	5.7
6/9 Bottom	0.21	2.73	93.6	90.6	86.2	6.0
6/9 Middle	0.15	2.72	89.7	85.1	78.9	5.8
6/9 Top	0.15	2.75	89.5	85.3	79.2	5.5

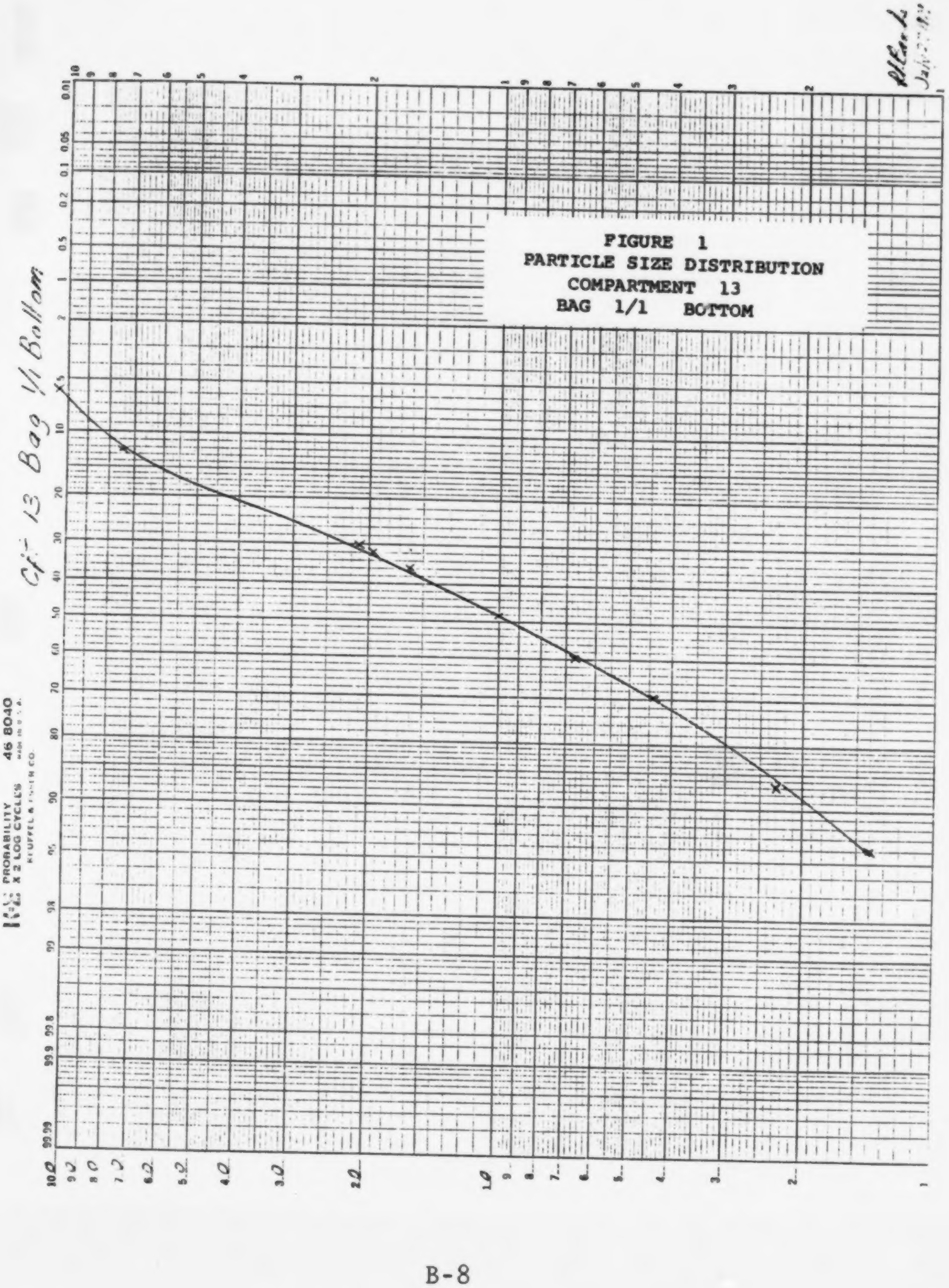


FIGURE 1
PARTICLE SIZE DISTRIBUTION
COMPARTMENT 13
BAG 1/1 BOTTOM

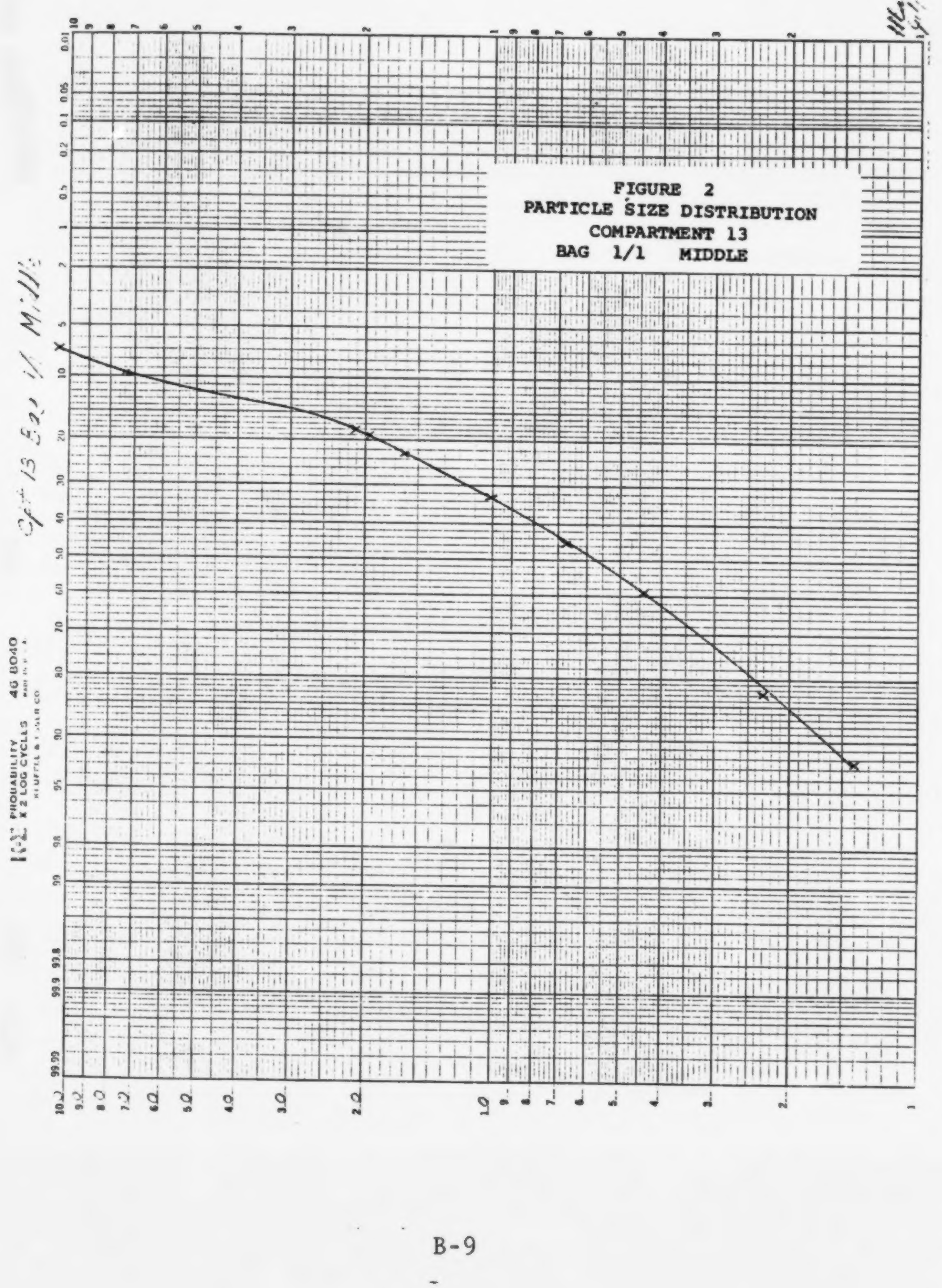


FIGURE 2
PARTICLE SIZE DISTRIBUTION
COMPARTMENT 13
BAG 1/1 MIDDLE

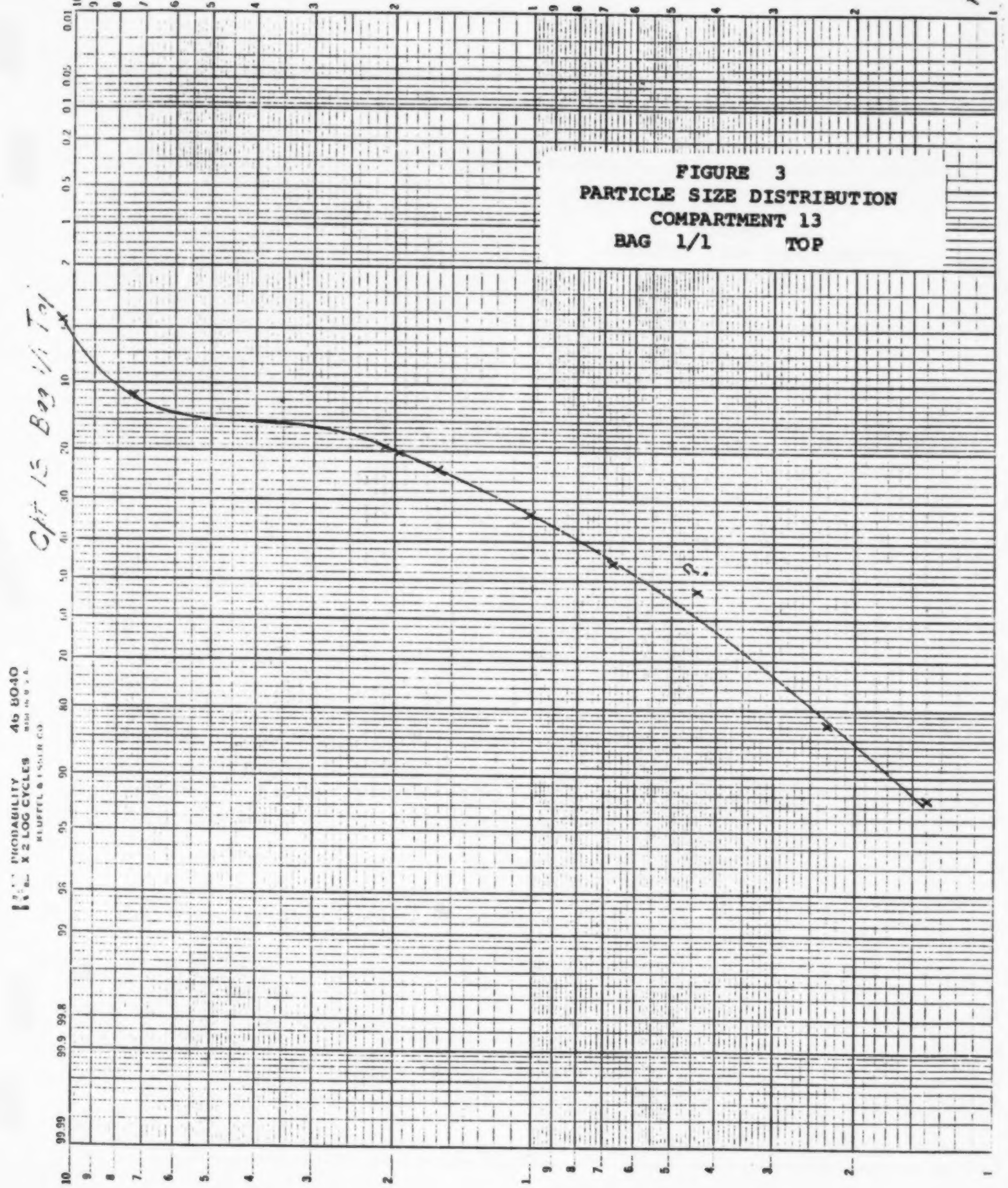


FIGURE 3
PARTICLE SIZE DISTRIBUTION
COMPARTMENT 13
BAG 1/1 TOP

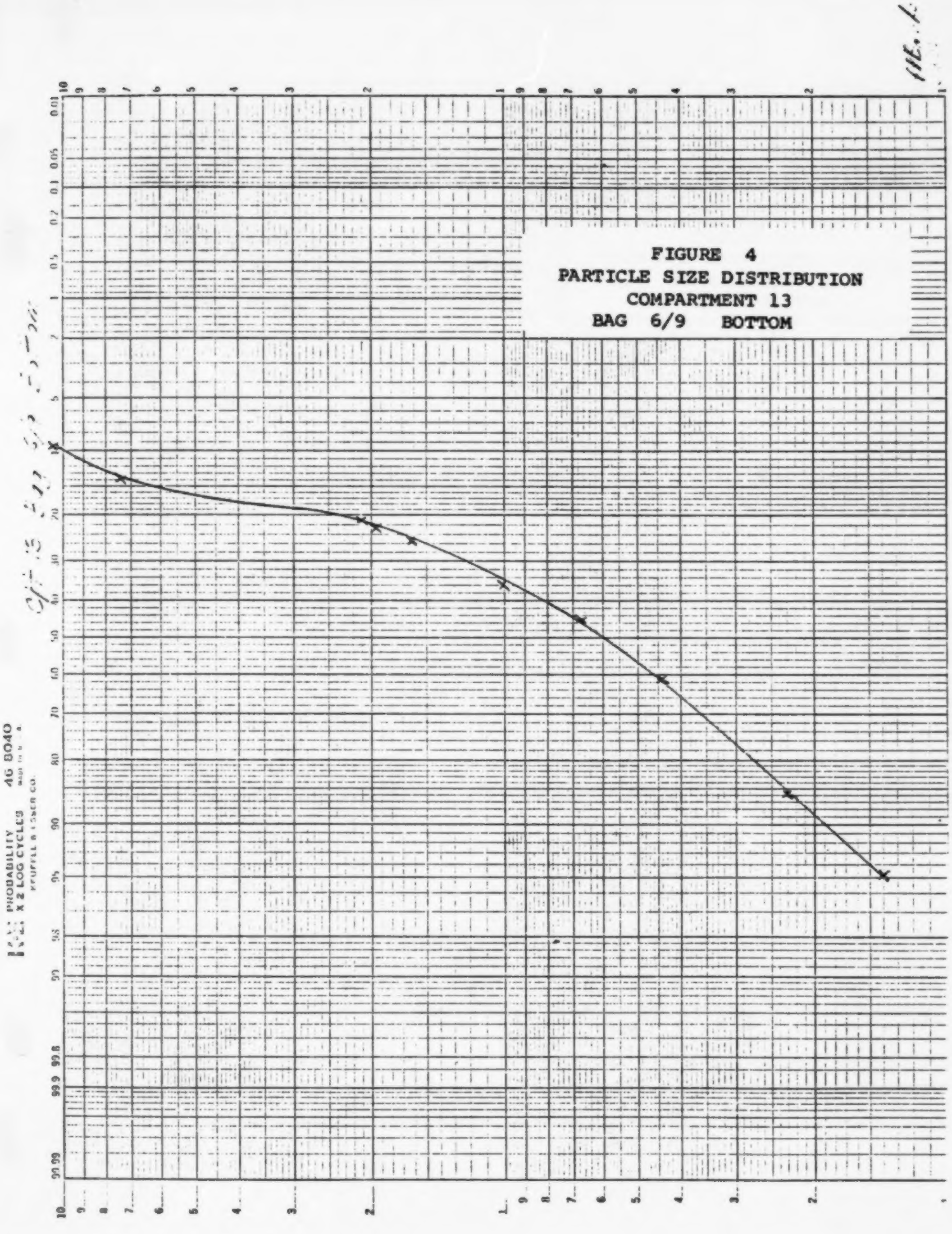


FIGURE 4
PARTICLE SIZE DISTRIBUTION
COMPARTMENT 13
BAG 6/9 BOTTOM

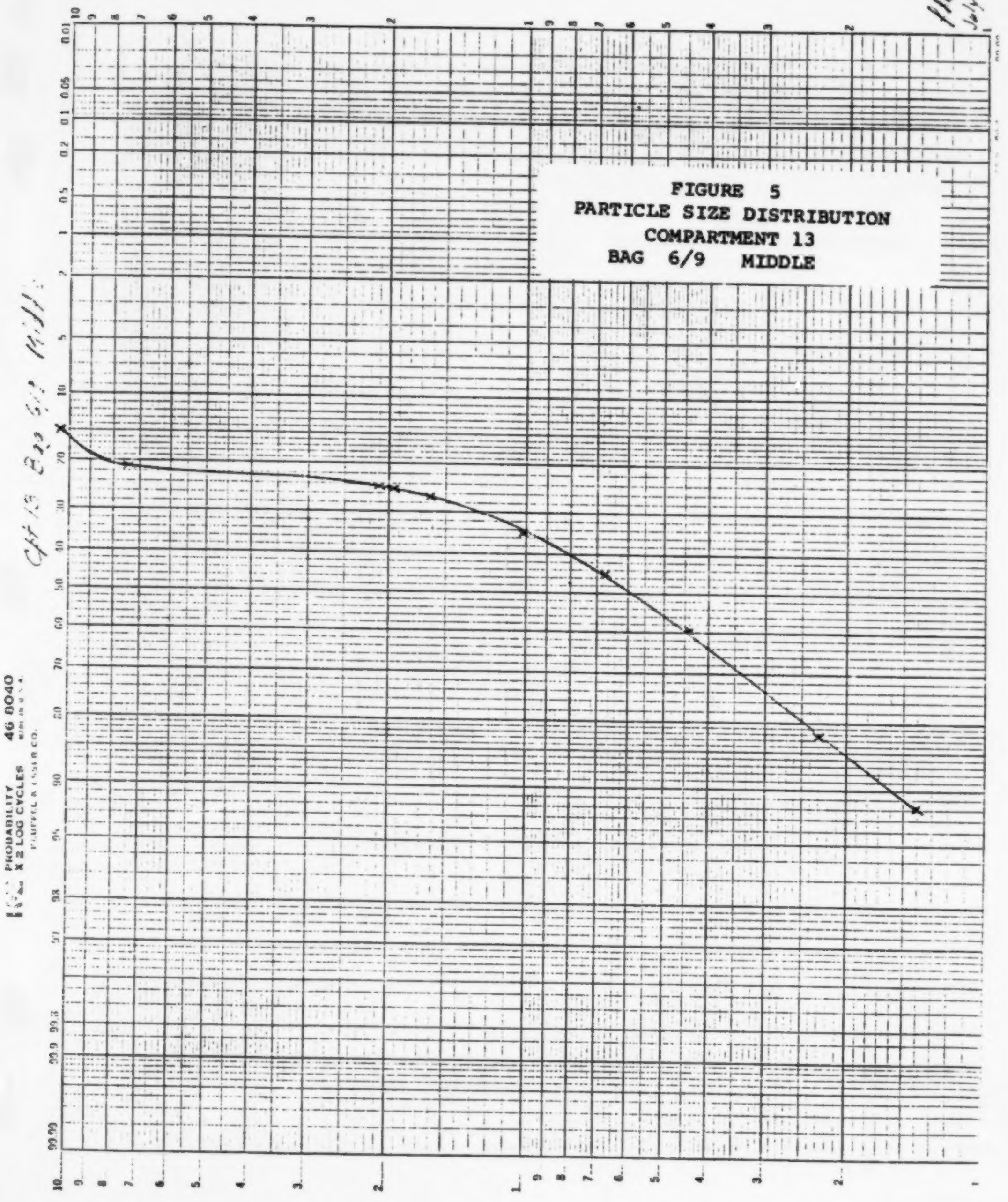


FIGURE 5
PARTICLE SIZE DISTRIBUTION
COMPARTMENT 13
BAG 6/9 MIDDLE

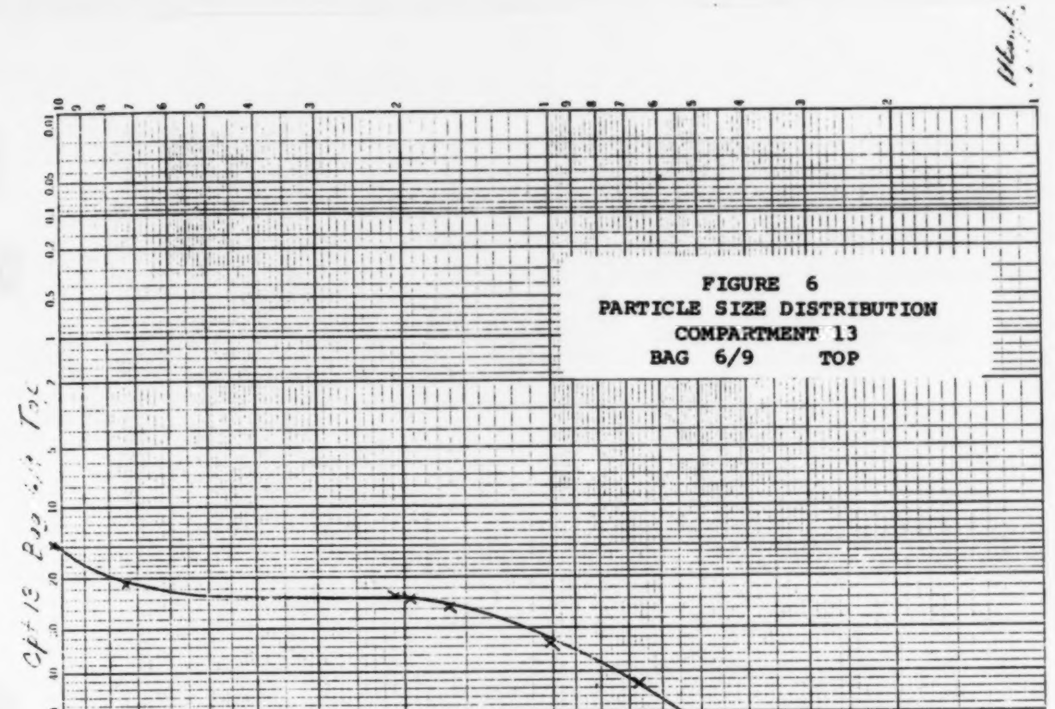


FIGURE 6
PARTICLE SIZE DISTRIBUTION
COMPARTMENT 13
BAG 6/9 TOP

a few more coarse particles than the others. This agrees with the particle size analyses.

The cloth samples were shaken gently to remove excess flyash before mounting for examination as the cloth structure would otherwise be completely hidden. The cloth does not show any broken fibers except for those broken in the bulking operation on the fill yarn. Dust remaining in the cloth does not appear to be firmly attached to the yarns.

Great difficulty was encountered in preparing the dust cake sample as the cake is very fragile and in addition the sputtering operation is complicated on that type of material. No indications of areas of strong attachment between flyash spheres were visible.

Copies of the micrographs are shown in the Appendix on pages 16 through 34 .

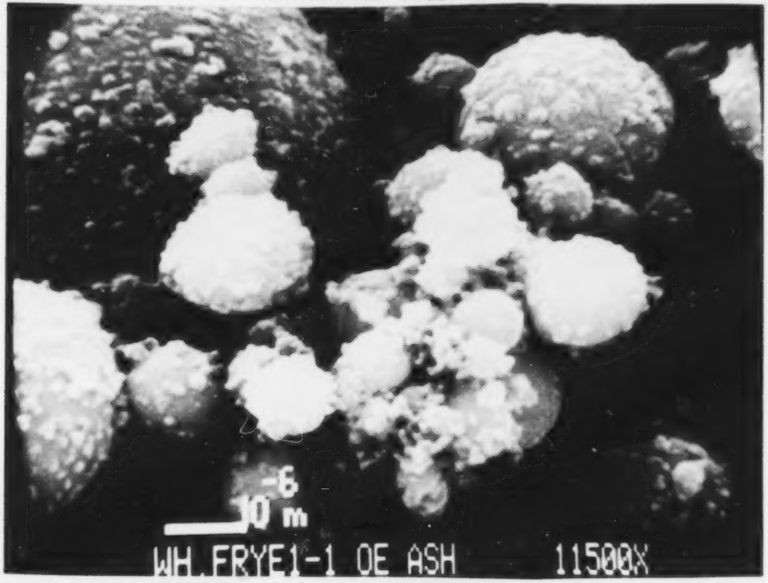
Tests on the condition of sections of the bags were carried out at the W.W. Criswell laboratory in Riverton, N.J. The permeability of the sections averaged about 2.7 cfm which is considered good for used, dirty filter cloth. The average permeability of the corner bag, which had the slightly coarser dust, was higher than that of the center bag but the scatter of the data is so great that little significance can be attached to the fact. Mullen burst tests averaged about 300 psi compared to 600 psi for new cloth. It is normal for fiberglass cloth to lose some strength rapidly when it is placed in service and then remain stable at a lower strength level. The burst strength of this cloth would be considered good. Loss on Ignition is lower than for new cloth because some of the silicone evaporates in service. The graphite in the finish provides adequate lubrication for the glass fibers even if all the silicone is vaporized. A copy of W. W. Criswell laboratory report is given in the Appendix (page 35).

RECOMMENDATIONS

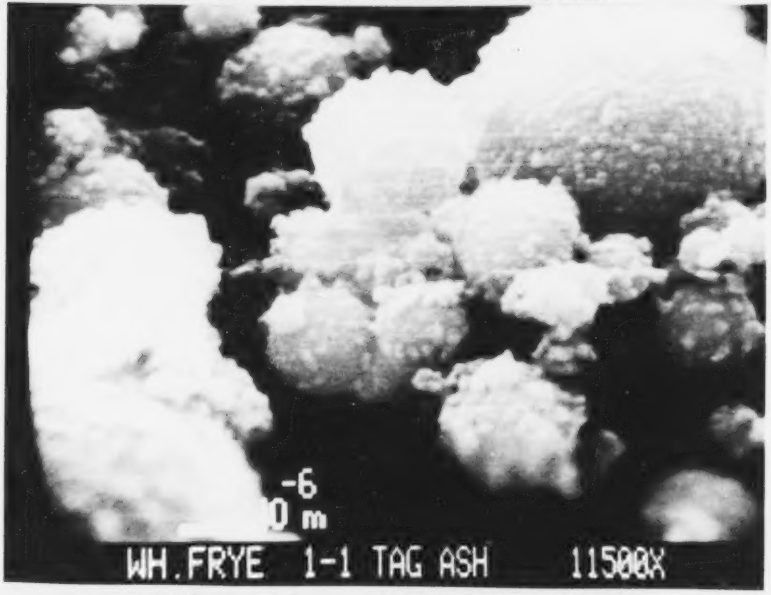
In view of the interesting results of the present study, it is recommended that additional testing of this type be carried out to confirm the results and expand the amount of data. This additional work should include the effect of position along the inlet plenum as well as the other variables.

APPENDIX

SCANNING ELECTRON MICROGRAPHS OF
FLYASH FROM DUSTUBES IN COMPARTMENT 13
HARRINGTON UNIT 2

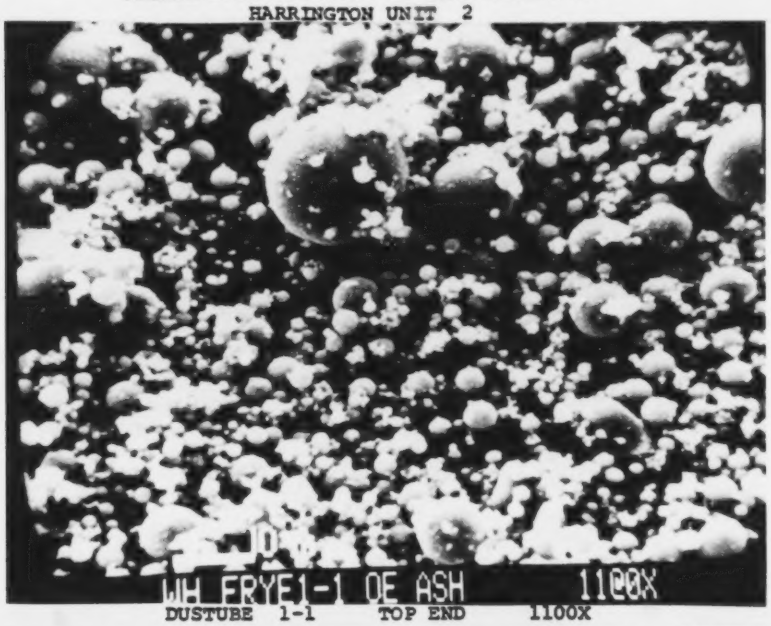

-6
10 m
WH.FRYE1-1 OE ASH 11500X

DUSTUBE 1-1 TOP END 11,500X

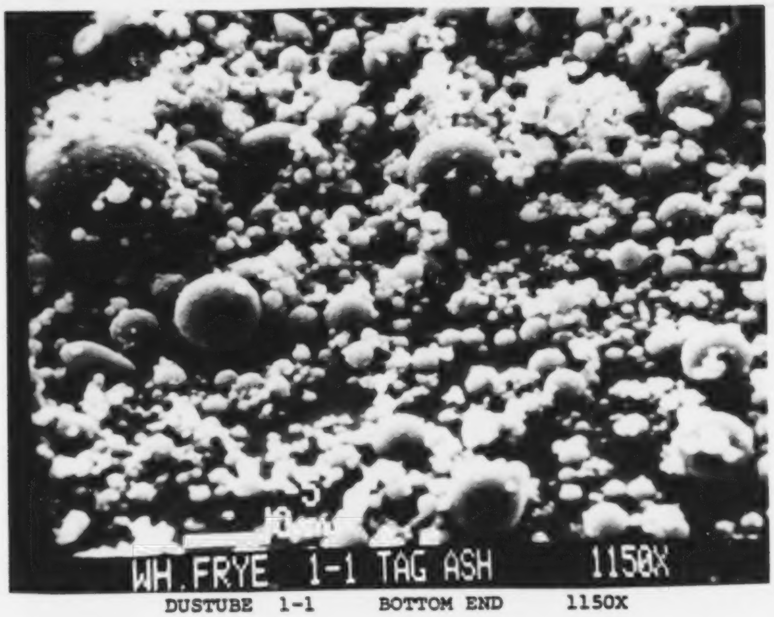

-6
0 m
WH.FRYE 1-1 TAG ASH 11500X

DUSTUBE 1-1 BOTTOM END 11,500X

SCANNING ELECTRON MICROGRAPHS OF
FLYASH FROM DUSTUBES IN COMPARTMENT 13
HARRINGTON UNIT 2

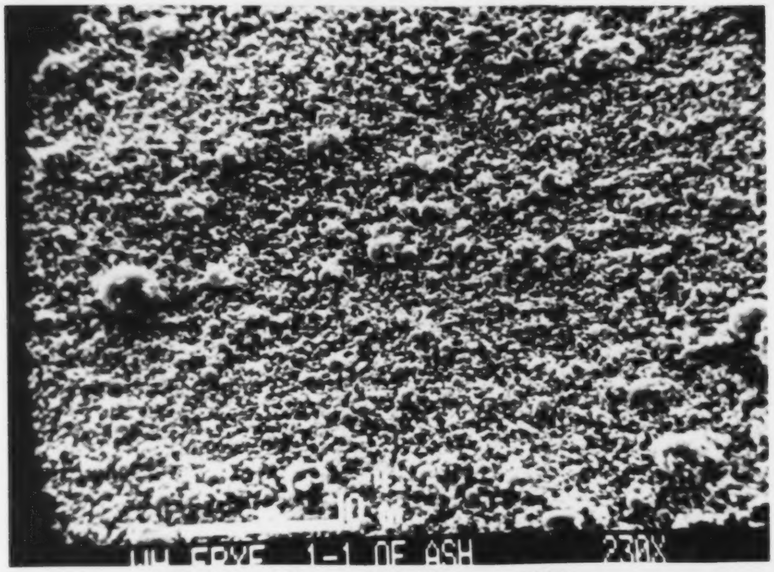

10
WH FRYE1-1 OE ASH 1100X

DUSTUBE 1-1 TOP END 1100X

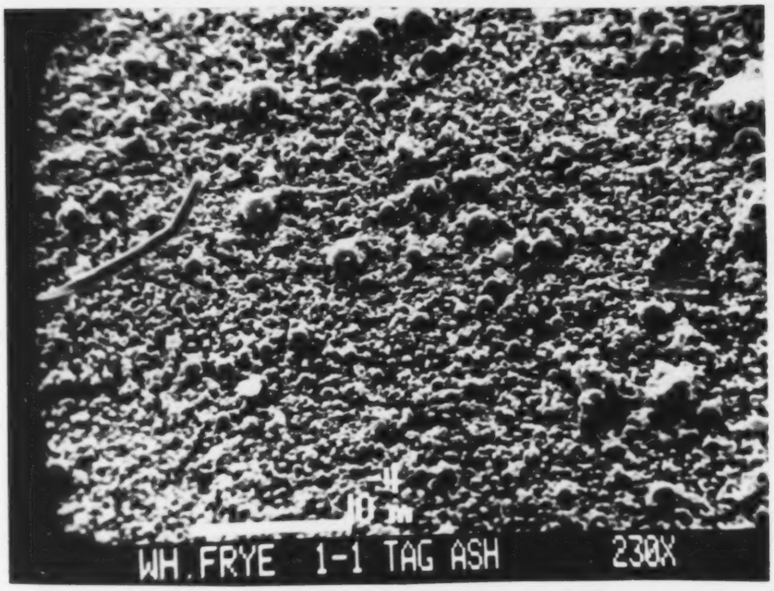

5
10
WH.FRYE 1-1 TAG ASH 1150X

DUSTUBE 1-1 BOTTOM END 1150X

SCANNING ELECTRON MICROGRAPHS OF
FLYASH FROM DUSTUBES IN COMPARTMENT 13
HARRINGTON UNIT 2

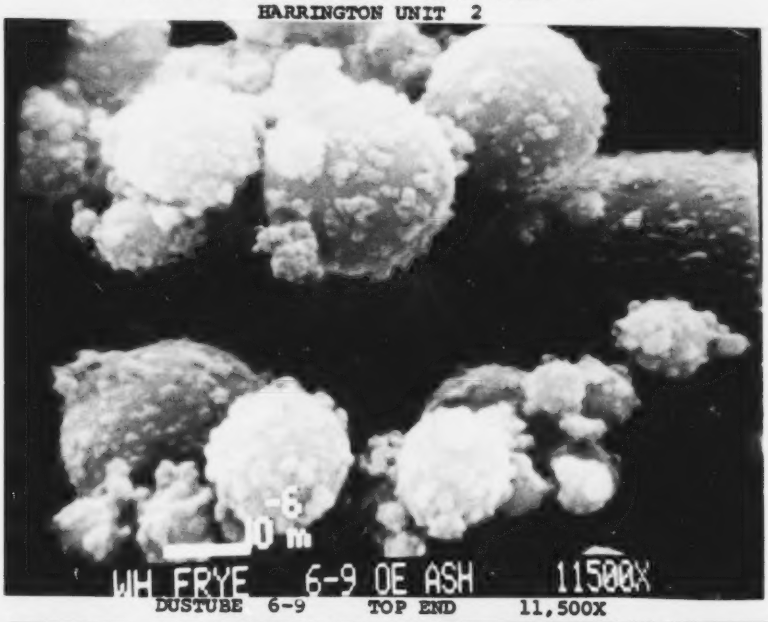

10 µm
WH.FRYE 1-1 OF ASH
230X

DUSTUBE 1-1 TOP END 230X

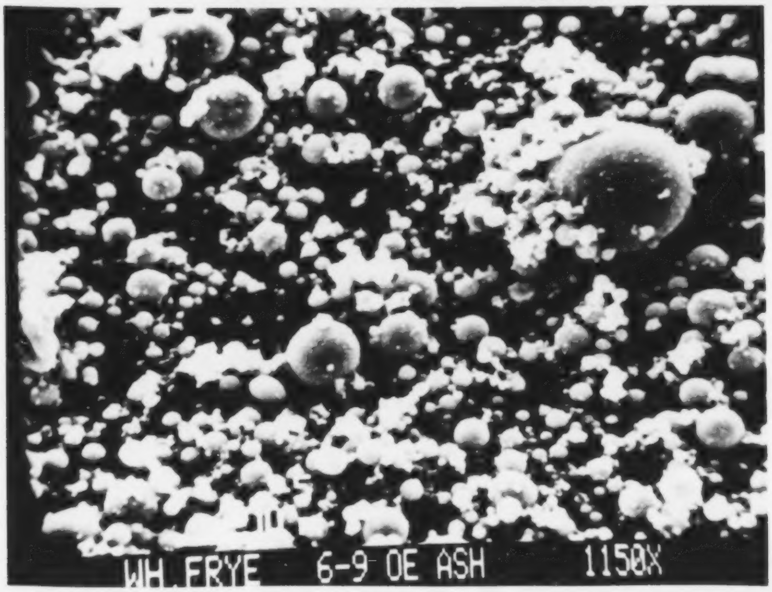

10 µm
WH.FRYE 1-1 TAG ASH
230X

DUSTUBE 1-1 BOTTOM END 230X

SCANNING ELECTRON MICROGRAPHS OF FLYASH FROM DUSTUBES IN COMPARTMENT 13 HARRINGTON UNIT 2

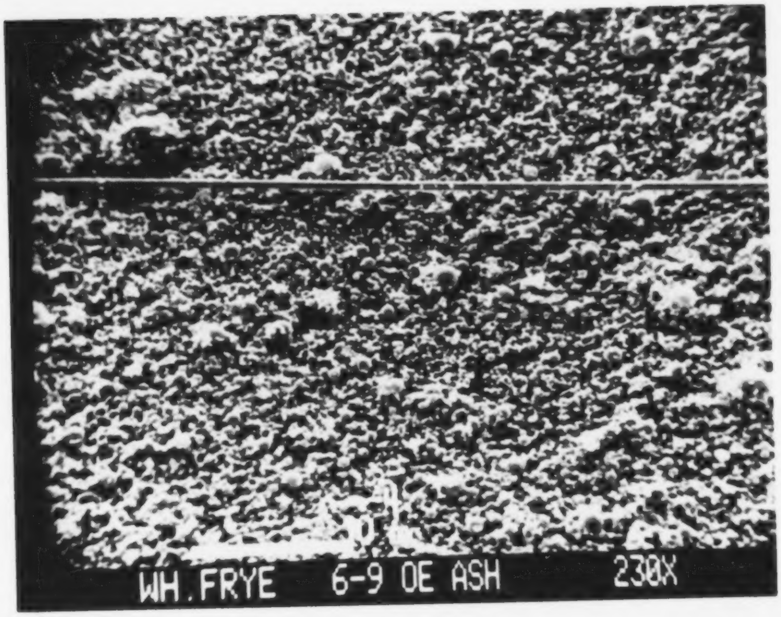

-6
10 m
WH FRYE 6-9 OE ASH 11500X

DUSTUBE 6-9 TOP END 11,500X


WH FRYE 6-9 OE ASH 1150X

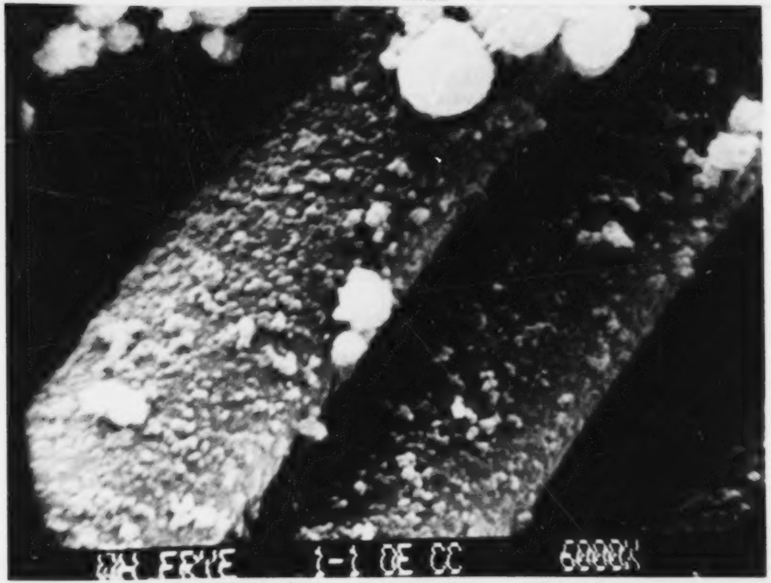
DUSTUBE 6-9 TOP END 1150X

SCANNING ELECTRON MICROGRAPHS OF
FLYASH FROM DUSTUBES IN COMPARTMENT 13
HARRINGTON UNIT 2

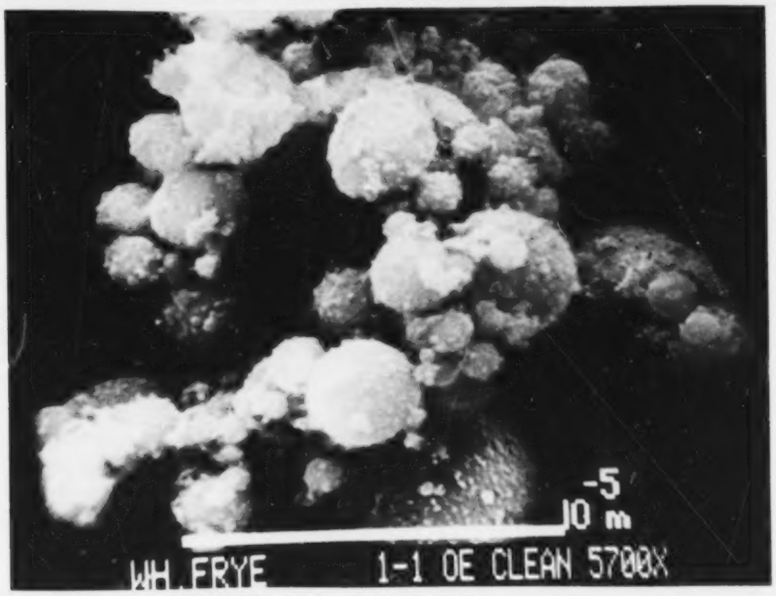

WH.FRYE 6-9 OE ASH 230X

Dustube 6-9 TOP END 230X

SCANNING ELECTRON MICROGRAPHS OF CLOTH FROM DUSTUBES IN COMPARTMENT 13 HARRINGTON UNIT 2

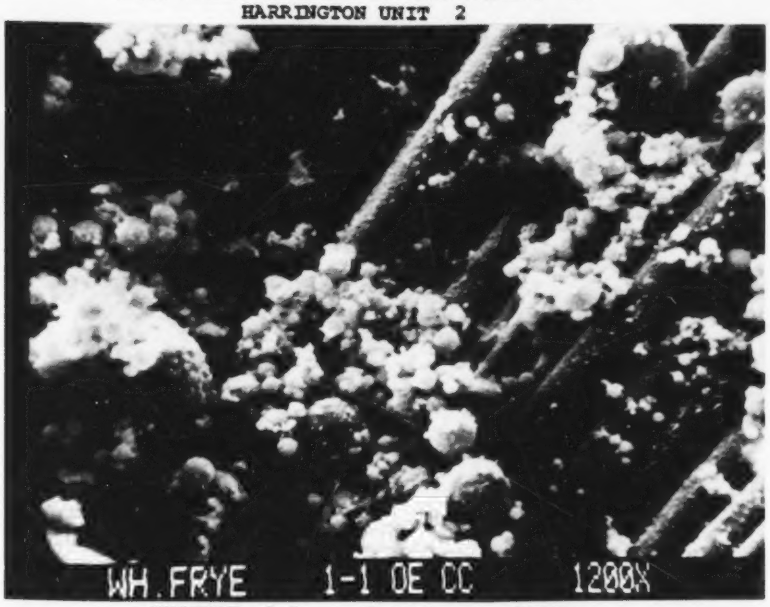

WH FRYE 1-1 OE CC 6000X

DUSTUBE 1-1 TOP END 6000X

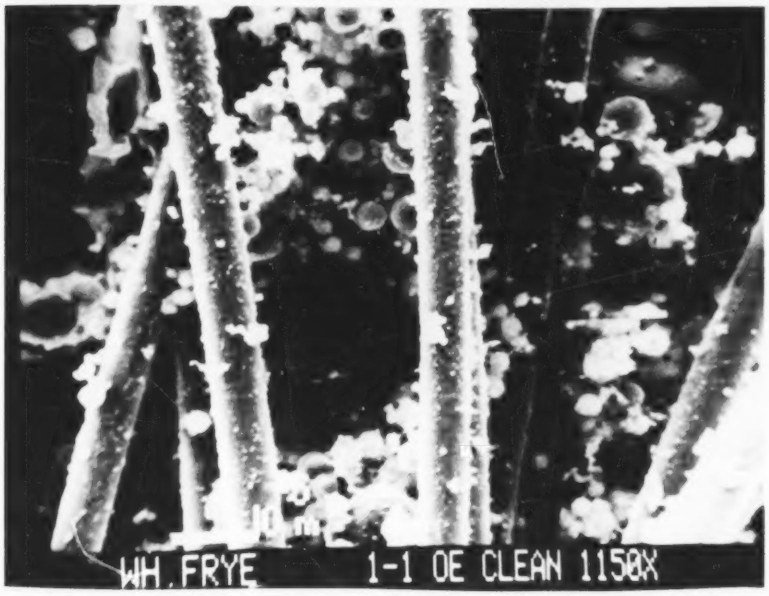

-5
10 m
WH FRYE 1-1 OE CLEAN 5700X

DUSTUBE 1-1 TOP END 5700X

SCANNING ELECTRON MICROGRAPHS OF
CLOTH FROM DUSTUBES IN COMPARTMENT 13
HARRINGTON UNIT 2

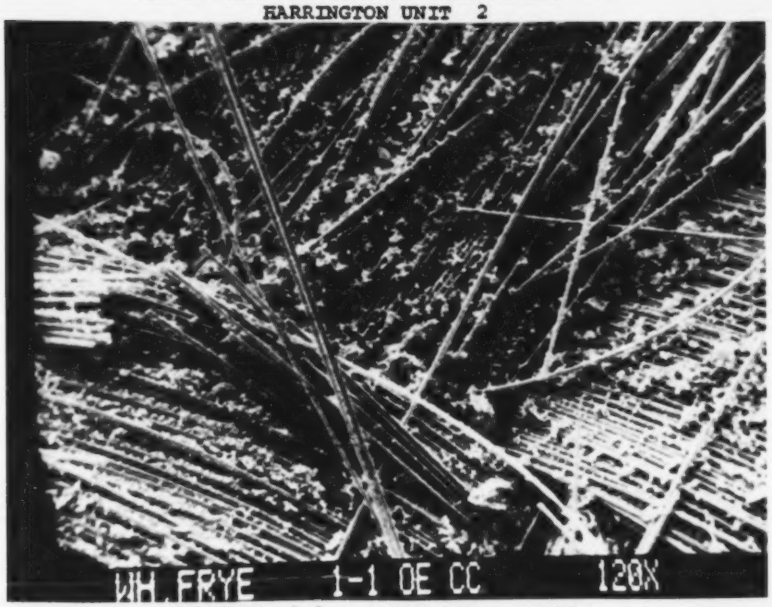

WH.FRYE
1-1 OE CC
1200X

DUSTUBE 1-1 TOP END 1200X

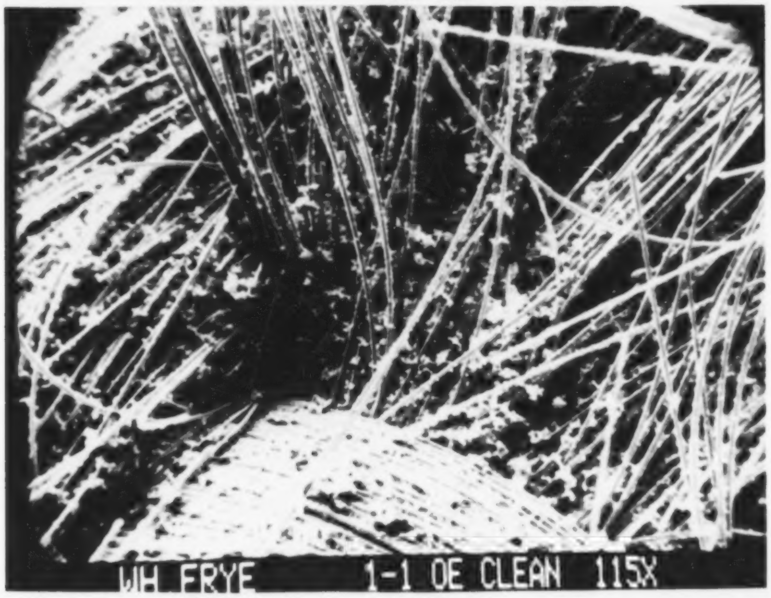

WH.FRYE
1-1 OE CLEAN 1150X

DUSTUBE 1-1 TOP END 1150X

SCANNING ELECTRON MICROGRAPHS OF
CLOTH FROM DUSTUBES IN COMPARTMENT 13
HARRINGTON UNIT 2

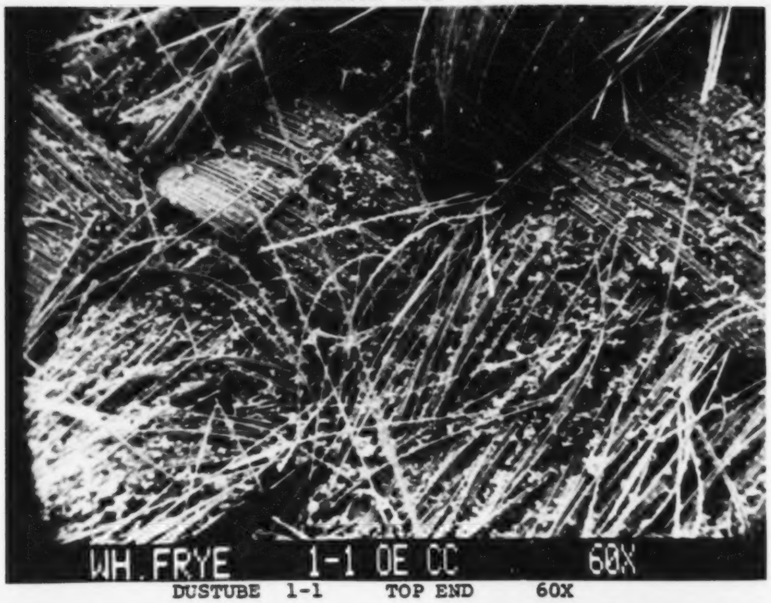

WH FRYE
1-1 OE CC
120X

DUSTUBE 1-1 TOP END 120X

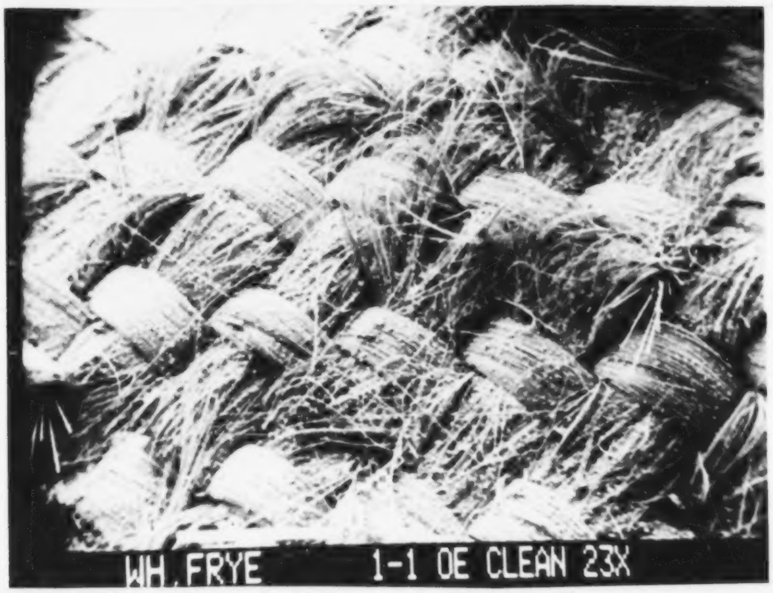

WH FRYE
1-1 OE CLEAN
115X

DUSTUBE 1-1 TOP END 115X

SCANNING ELECTRON MICROGRAPHS OF
CLOTH FROM DUSTUBES IN COMPARTMENT 13
HARRINGTON UNIT 2

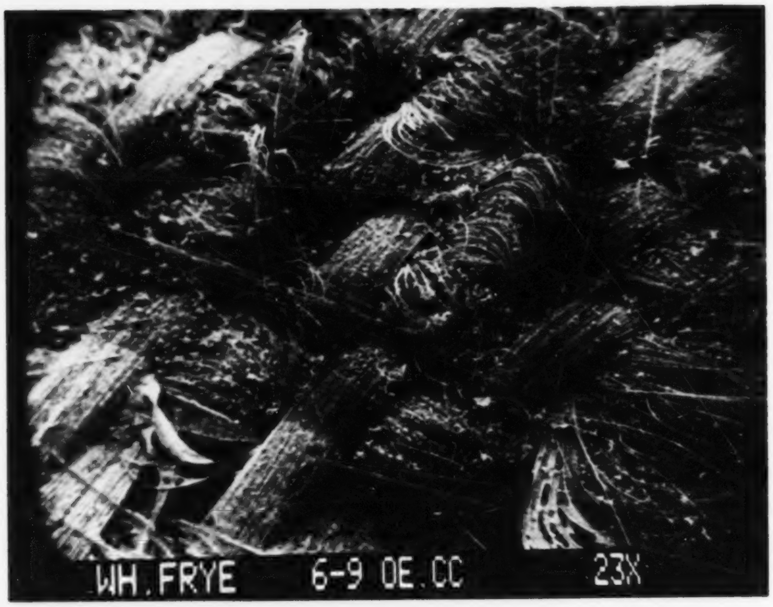

WH.FRYE 1-1 OE CC 60X

DUSTUBE 1-1 TOP END 60X


WH.FRYE 1-1 OE CLEAN 23X

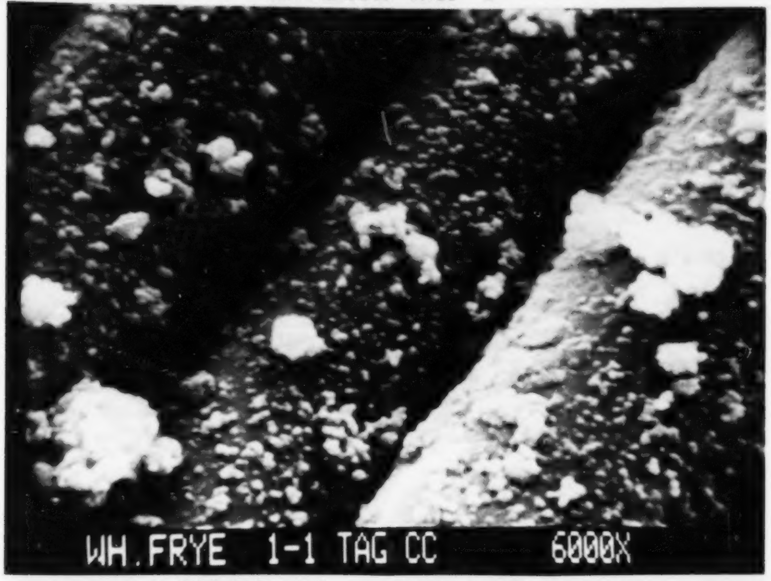
DUSTUBE 1-1 TOP END 23X

SCANNING ELECTRON MICROGRAPHS OF
CLOTH FROM DUSTUBES IN COMPARTMENT 13
HARRINGTON UNIT 2

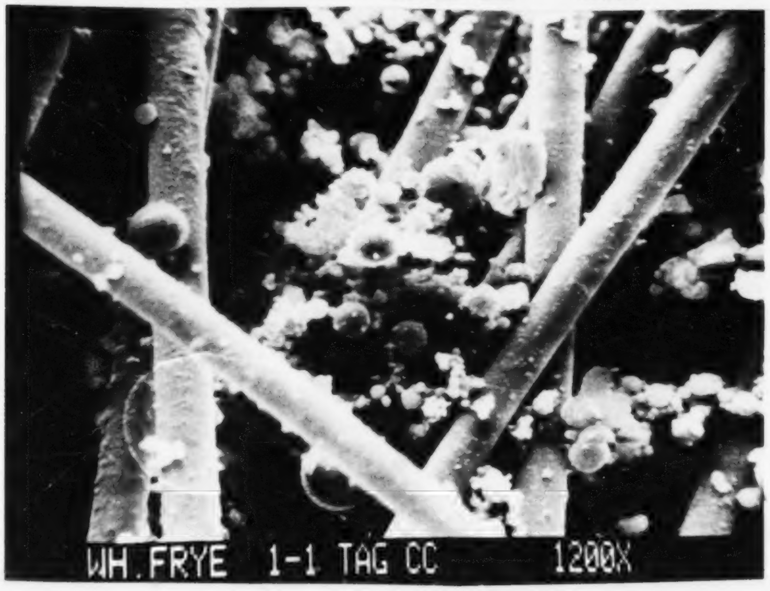

WH.FRYE 6-9 OE.CC 23X

DUSTUBE 1-1 TOP END 23X

SCANNING ELECTRON MICROGRAPHS OF
CLOTH FROM DUSTUBES IN COMPARTMENT 13
HARRINGTON UNIT 2

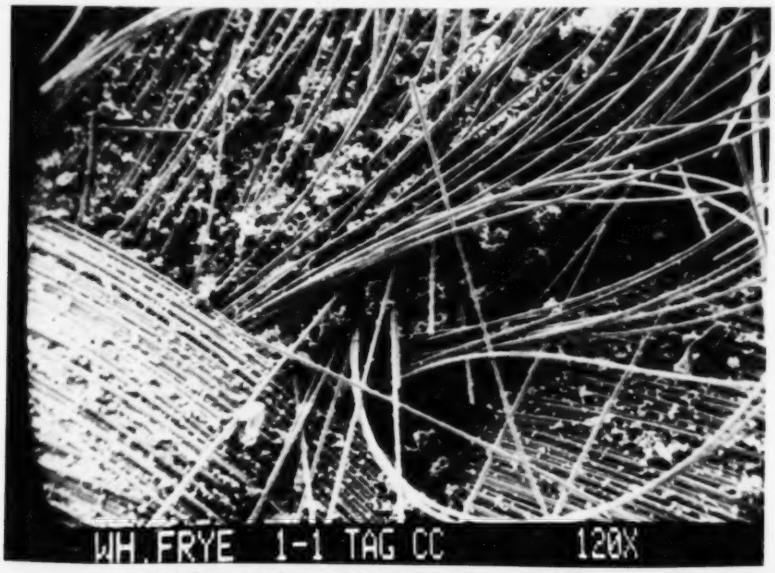

WH.FRYE 1-1 TAG CC 6000X

DUSTUBE 1-1 BOTTOM END 6000X

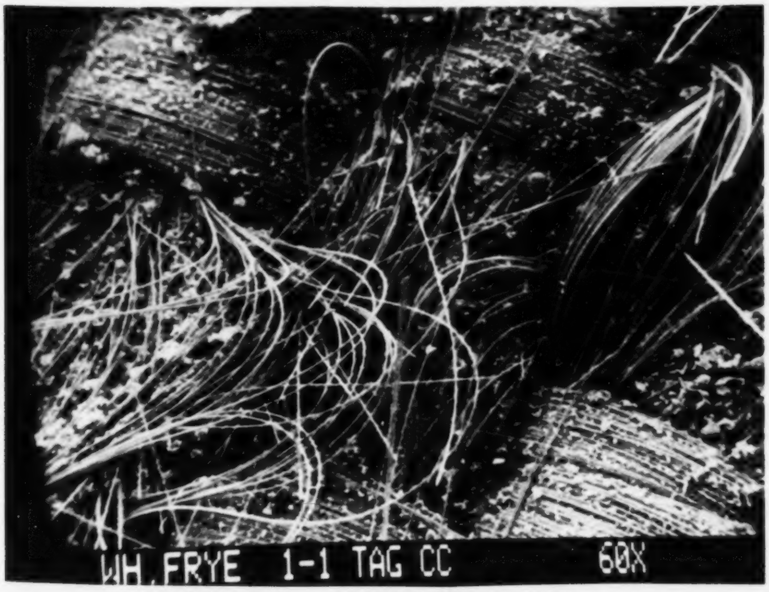

WH.FRYE 1-1 TAG CC 1200X

DUSTUBE 1-1 BOTTOM END 1200X

SCANNING ELECTRON MICROGRAPHS OF
CLOTH FROM DUSTUBES IN COMPARTMENT 13
HARRINGTON UNIT 2

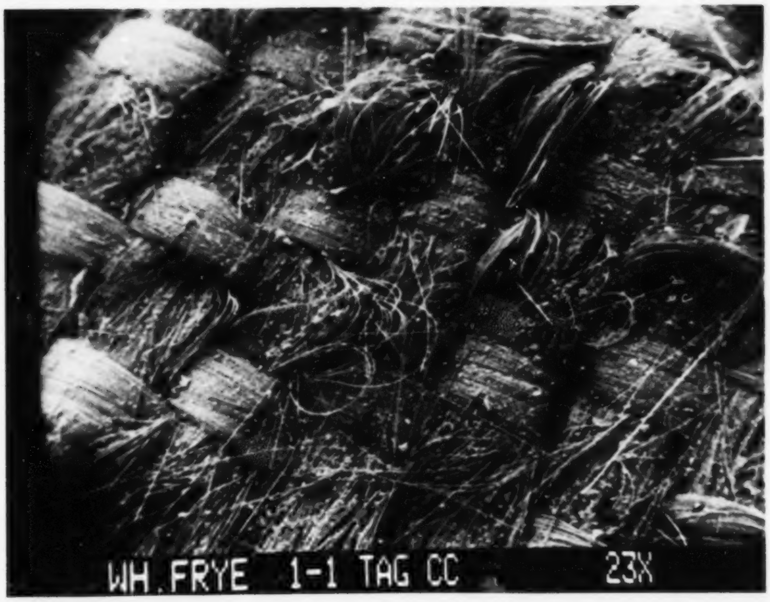

WH.FRYE 1-1 TAG CC 120X

DUSTUBE 1-1 BOTTOM END 120X


WH.FRYE 1-1 TAG CC 60X

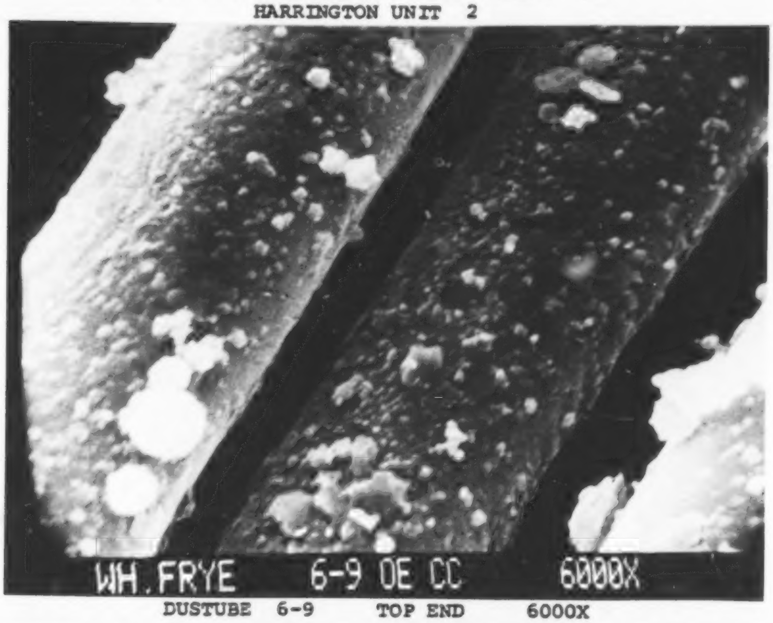
DUSTUBE 1-1 BOTTOM END 60X

SCANNING ELECTRON MICROGRAPHS OF
CLOTH FROM DUSTUBES IN COMPARTMENT 13
HARRINGTON UNIT 2

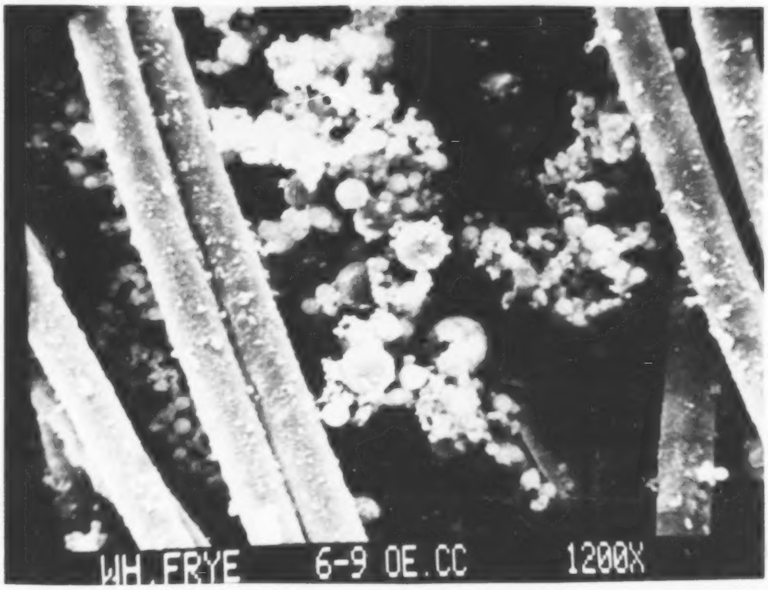

WH.FRYE 1-1 TAG CC
23X

DUSTUBE 1-1 BOTTOM END 23X

SCANNING ELECTRON MICROGRAPHS OF
CLOTH FROM DUSTUBES IN COMPARTMENT 13
HARRINGTON UNIT 2

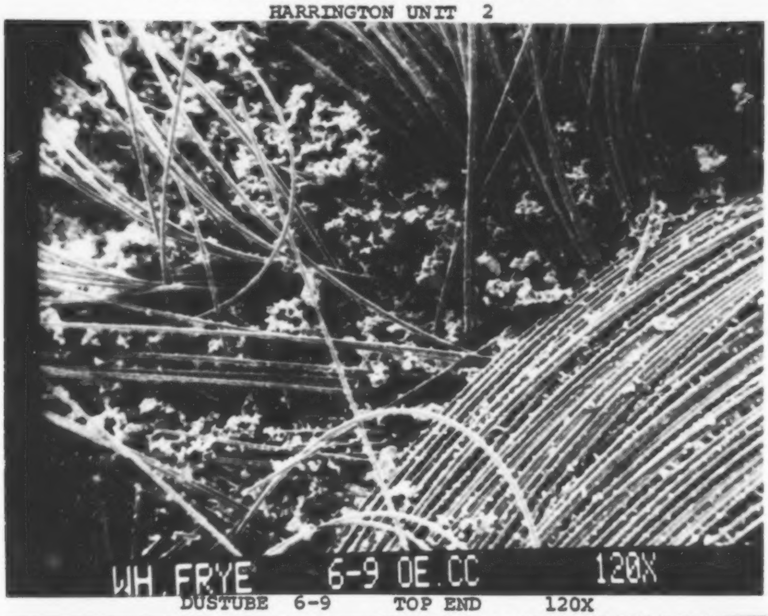

WH.FRYE 6-9 OE CC 6000X

DUSTUBE 6-9 TOP END 6000X

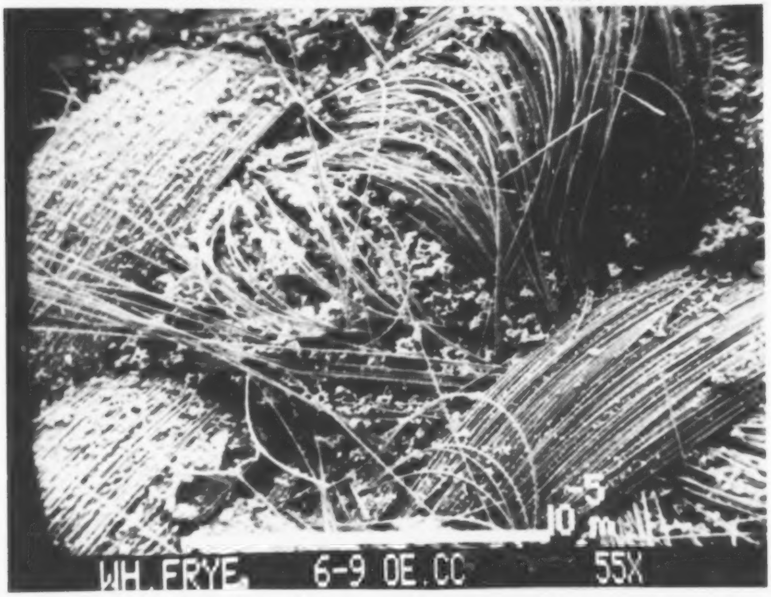

WH.FRYE 6-9 OE.CC 1200X

DUSTUBE 6-9 TOP END 1200X

SCANNING ELECTRON MICROGRAPHS OF
CLOTH FROM DUSTUBES IN COMPARTMENT 13
HARRINGTON UNIT 2

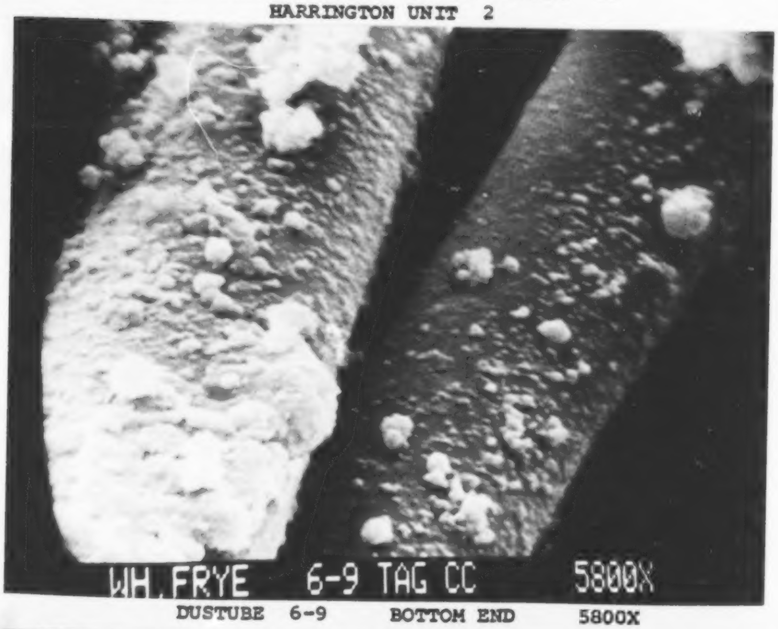

WH.FRYE 6-9 OE.CC 120X

DUSTUBE 6-9 TOP END 120X

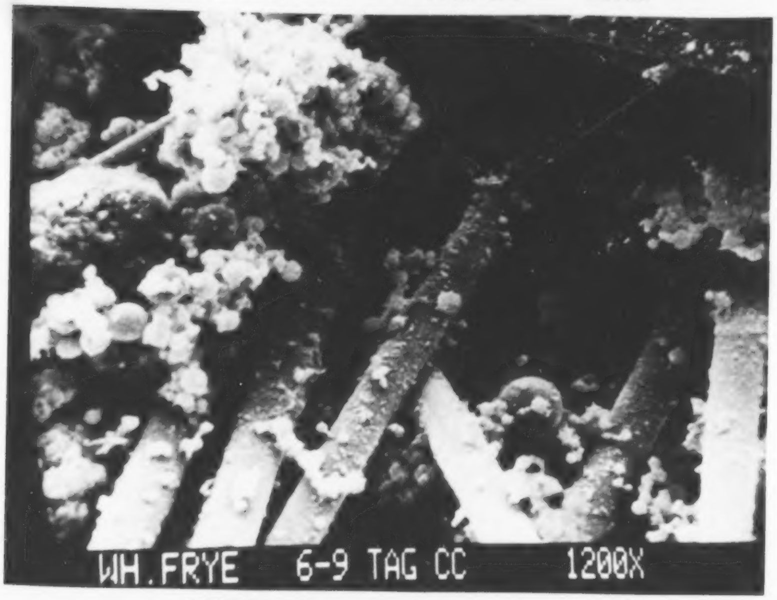

10^{-5} m
WH.FRYE 6-9 OE.CC 55X

DUSTUBE 6-9 TOP END 55X

SCANNING ELECTRON MICROGRAPHS OF
CLOTH FROM DUSTUBES IN COMPARTMENT 13
HARRINGTON UNIT 2

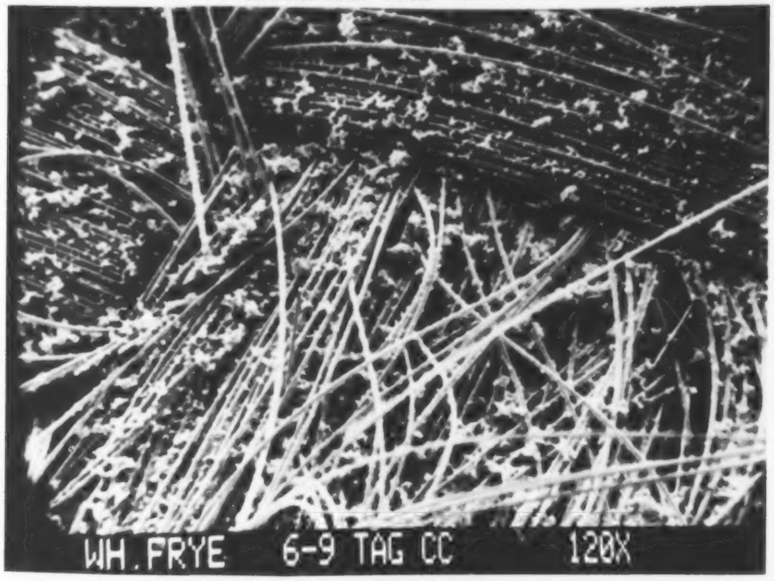

WH.FRYE 6-9 TAG CC 5800X

DUSTUBE 6-9 BOTTOM END 5800X

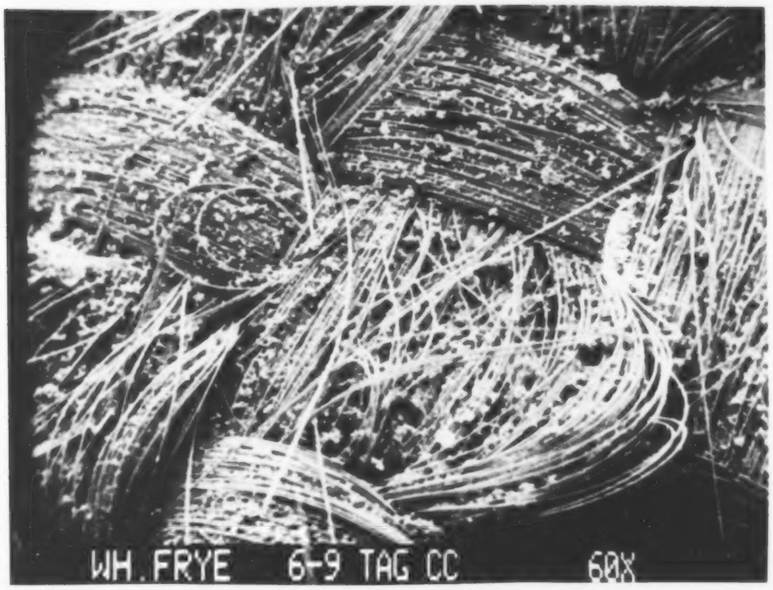

WH.FRYE 6-9 TAG CC 1200X

DUSTUBE 6-9 BOTTOM END 1200X

SCANNING ELECTRON MICROGRAPHS OF
CLOTH FROM DUSTUBES IN COMPARTMENT 13
HARRINGTON UNIT 2

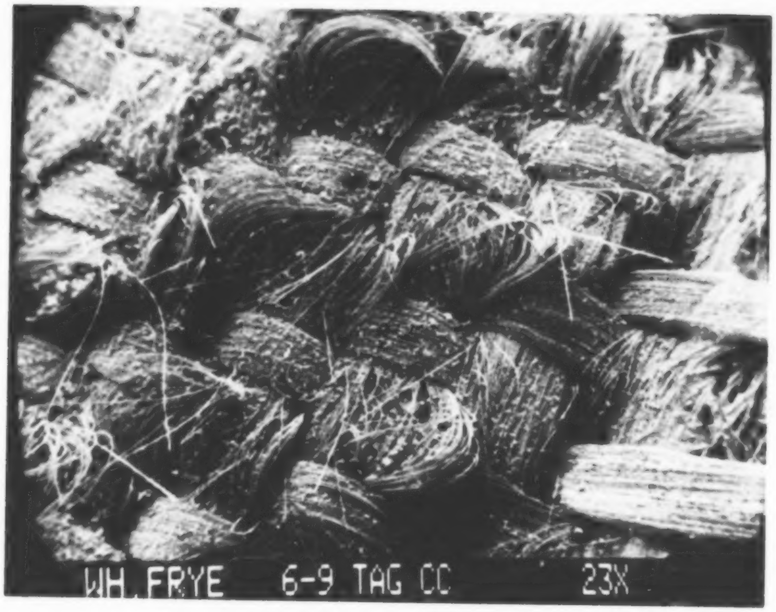

WH.FRYE 6-9 TAG CC 120X

DUSTUBE 6-9 BOTTOM END 120X


WH.FRYE 6-9 TAG CC 60X

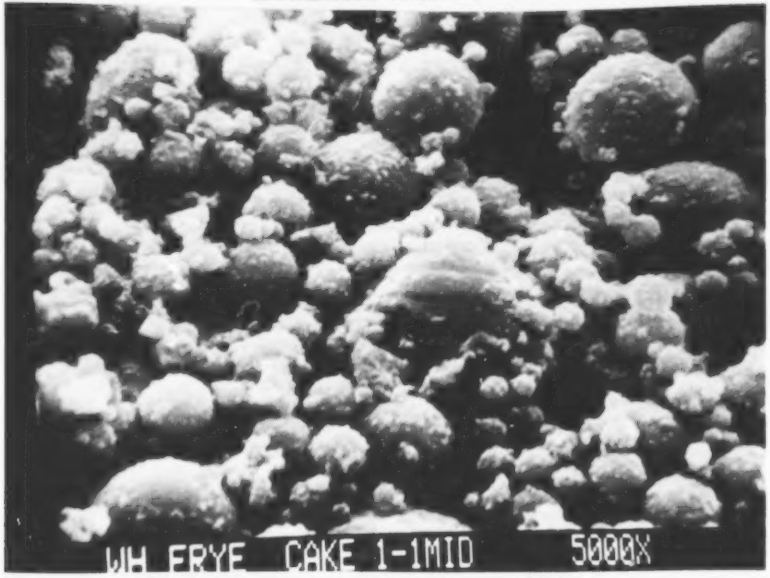
DUSTUBE 6-9 BOTTOM END 60X

SCANNING ELECTRON MICROGRAPHS OF
CLOTH FROM DUSTUBES IN COMPARTMENT 13
HARRINGTON UNIT 2

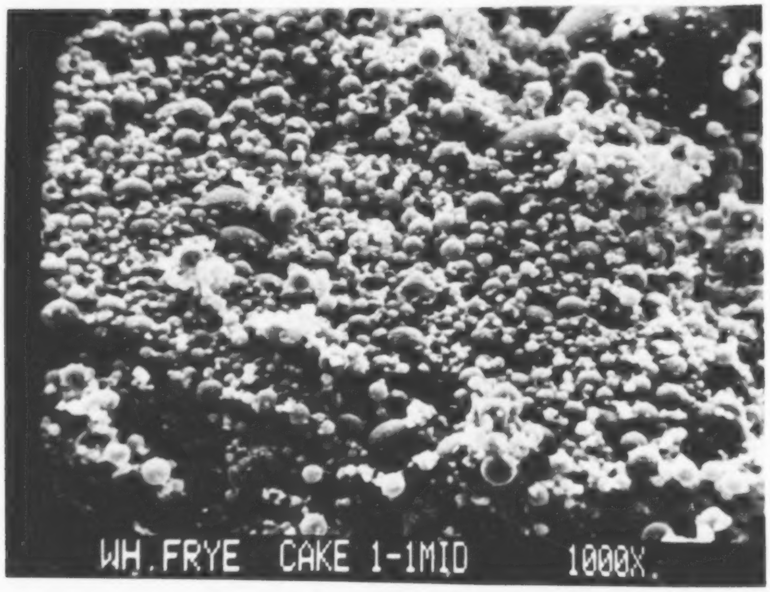

WH.FRYE 6-9 TAG CC 23X

DUSTUBE 6-9 BOTTOM END 23X

SCANNING ELECTRON MICROGRAPHS OF
DUST CAKE FROM DUSTUBE IN COMPARTMENT 13
HARRINGTON UNIT 2


WH FRYE CAKE 1-1MID 5000X

DUSTUBE 1-1 MIDDLE 5000X


WH.FRYE CAKE 1-1MID 1000X

DUSTUBE 1-1 MIDDLE 1000X

W. W. CRISWELL CO.

LABORATORY REPORT

Report № 6862

Date 8-12-79

From R. R. Banks
W/F Mishawaka

Specimen: Top, middle and bottom sections from two used 3/445-04 bags, 11-1/2" diameter x 30 feet 8-3/4" long. In service on fly ash from a lignite fired boiler.

Origin. TEXAS UTILITIES SERVICES INC., MT. PLEASANT, TEXAS

Query: Check dirty permeability, Mullen strength and LOI.

Observations: Received 3 ft. long top, middle and bottom sections of bags 1/1 and 6/9, compartment unknown. The sections from both bags were in good condition with no failures evident. Both bags did have a band of somewhat firm edge treatment running along the vertical seam, but no detrimental consequences were apparent. S.O. #T-68031 was visible at the top of bag 1/1, no number visible on bag 6/9.

		Perm^F (new 45/65 CFM)	Mullen (new 600 psi)
1/1	Top	2.5-1.9-5.0 = 3.13	270-290-315-345-265 = 297
	Middle	2.4-2.2-2.0 = 2.20	385-255-345-275-265 = 305
	Bottom	4.8-2.0-5.9 = 4.23	460-435-315-305-270 = 357
	O.A.Avg.	3.19 CFM	320 PSI

LOI, middle (vacuumed): 0.89%

		Perm^F (new 45/60 CFM)	Mullen (new 600 psi)
6/9)	Top	1.8-2.5-2.3 = 2.20	310-335-400-335-315 = 339
	Middle	2.6-2.2-3.1 = 2.60	270-285-275-300-260 = 278
	Bottom	1.4-1.8-2.1 = 1.77	255-245-215-285-210 = 242
	O.A.Avg.	2.19 CFM	283 PSI

LOI, middle (vacuumed): 0.85%

In later phone conversation it developed that although bags were from Southwestern order No was for TUSI. RRB

APPENDIX C. ACUREX MOBIL BAGHOUSE STUDY

MOBILE FABRIC FILTER TEST PLAN

HARRINTON STATION, AMARILLO, TEXAS

PREPARED UNDER

CONTRACT NO. 68-02-2646

FOR

ENVIRONMENTAL PROTECTION AGENCY

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY

RESEARCH TRIANGLE PARK, N.C. 27711

BY: W.O. LIPSCOMB

ACUREX CORPORATION/ENERGY AND ENVIRONMENTAL DIVISION

FEBRUARY 1979

1.0 INTRODUCTION AND OBJECTIVES

2.0 FACILITIES DESCRIPTION

- 2.1 Site Description
- 2.2 Mobile Fabric Filter Description
- 2.3 Site Installation

3.0 TEST PROGRAM

- 3.1 Strategy and Methodology
- 3.2 Test Design and Schedule

4.0 PERFORMANCE MEASUREMENTS

- 4.1 Operational Data
- 4.2 Particulate Concentration and Size
- 4.3 Humidity and Static Charge
- 4.4 Cake Resistance Coefficient
- 4.5 Coal and Ash Analyses

1.0 INTRODUCTION AND OBJECTIVES

The purpose of this test plan is to summarize the pertinent aspects of the test program utilizing the U.S. Environmental Protection Agency (EPA) Mobile Fabric Filter Unit at Harrington Station, Amarillo, Texas.

Pursuant to a request by Southwestern Public Service Company (SWPSCo), Amarillo, Texas the EPA Mobile Baghouse will be made available for a test program at SWPSCo's Harrington Station. The general objective of the effort will be to screen potential new bag candidates for the existing (Unit 2) and planned (Unit 3) full scale baghouses with respect to operating characteristics and performance.

The specific program objectives will be to provide such data on new bag candidates as required by SWPSCo to facilitate selection of a bag material and cleaning mode to improve present operational deficiencies.

2.0 FACILITIES DESCRIPTION

2.1 Site Description: Harrington Station is owned and operated by SWPSCo. The facility consists of two 350 MW pulverized coal-fired boilers. Unit 1 is equipped with an ESP and a marble-bed wet scrubber while Unit 2 is equipped with a (Wheelabrator-Frye) Baghouse. Unit 2 went on line in June of 1978 and plans call for a third unit, also equipped with a baghouse, to be brought on line in 1980. With the exception of the particulate control devices Units 1 and 2 are identical.

Harrington Station generally burns low-sulfur Western coal from Wyoming. Due to the severe winter, rail delivery of Wyoming coal has been interrupted and coal from New Mexico is currently being burned in Unit 1, with Unit 2 continuing to burn Wyoming coal. The New Mexico coal has twice the ash content as the Wyoming coal and is not suitable for Unit 2 due to inadequate capacity in the ash handling system and a projected pressure drop in excess of 12" H_2O. Unit 2 is presently experiencing operating problems with a pressure drop of 9-10" H_2O and bag failures to an extent that a maximum of six months additional life has been projected by SWPSCo.

2.2 Mobile Baghouse Description: The mobile baghouse consists of a single compartment containing three 5 9/16" diameter by 6' long bags. Designed for the purpose of determining the effects of dust properties, fabric media, cleaning parameters and other operating parameters on fabric filter performance, the system has the following capabilities:

- Filtration at cloth velocities as high as 20 fpm with a pressure differential up to 20 inches of water and at gas temperatures up to 500°F.
- Adaptability of mobile system to cleaning by mechanical shake, pulse jet, or low pressure reverse flow with cleaning parameters varying over a wide range.
- Continuous 24-hour operation with use of automatic instruments and controls.

The mobile fabric filter, shown schematically in Figure 1, is housed in an 8 ft. by 40 ft. tandem-axle trailer and provides the experimental flexibility of a laboratory investigation and the real-world particulate effluent of an industrial source.

2.3 Mobile Baghouse Installation: The mobile baghouse will be located adjacent to Unit 1 and a slipstream consisting of 2 1/2" schedule 5 stainless steel tubing will connect the unit to the process. The slipstream will be taken from the process downstream from the air-preheater and ahead of the ESP. The slipstream probe will be sized and located in the process duct to provide approximately isokinetic draw-off of a representative flue gas. A return line will be installed back to the process from the mobile baghouse to facilitate adequate blower capacity on the mobile unit due to a high negative static pressure in the process duct. The return line will connect to the process downstream from the slipstream connection. It is estimated that the slipstream and return line will each be 110-120' long. The slipstream will be heated and insulated to provide operating temperatures in the mobile unit from 300-350°F. The return line will be insulated but no heating capability will be provided.

3.0 TEST PROGRAM

The general philosophy and specific technical criteria and objection of this program are contained in the following sections.

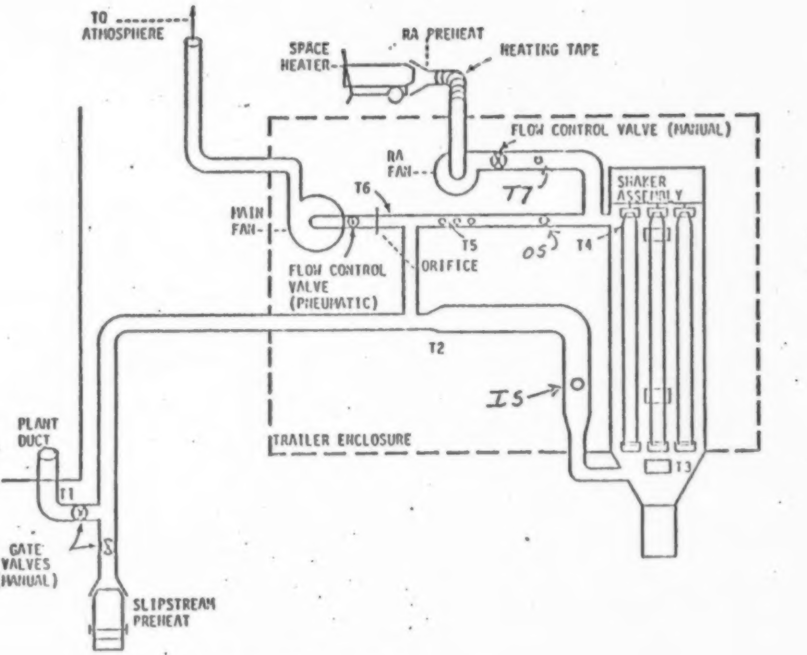

TO ATMOSPHERE
SPACE HEATER
RA PREHEAT
HEATING TAPE
FLOW CONTROL VALVE (MANUAL)
RA FAN
T7
SHAKER ASSEMBLY
T6
MAIN FAN
T5
OS
T4
FLOW CONTROL VALVE (PNEUMATIC)
ORIFICE
T2
IS
PLANT DUCT
TRAILER ENCLOSURE
T1
T3
GATE VALVES (MANUAL)
SLIPSTREAM PREHEAT

Figure 1. Mobile baghouse schematic

TI-6 — thermocouples with digital readout
PI-4 — static pressure
RA — reverse air

IS — inlet sampling ports
OS — outlet sampling ports

3.1 Strategy and Methodology: In the past several years, fabric filtration has become an accepted control technology for particulate emissions from coal-fired boilers and is recognized in some circles as the best available control technology (BACT). This is particularly true for boilers firing low-sulfur Western coal due to difficulties experienced with electrostatic precipitators as a method of particulate control. Harrington Station is one of only a few baghouses in this country applied to a boiler firing Western coal.

Because of the operational problems experienced to date at Harrington Station, i.e. excessive pressure drop across the bags, the status of fabric filtration as demonstrated control technology for Western coal-fired boilers depends to some degree on the operational success of this installation. A timely solution therefore is important not only to Harrington Station specifically, but also to the utility industry in general.

The primary cause of excessive pressure drop across the Harrington Station baghouse is uncertain. In light of this uncertainty several parameters have been identified for investigation. The test program with the mobile baghouse will consist of two phases:

- A screening of existing bags and potential new bag candidates.
- An optimization of operating parameters for the more attractive bag candidates.

Selection and procurement of bag candidates will be the responsibility of SWPSCo.

3.2 Test Program and Schedule: The mobile baghouse will be slipstreamed from Unit 1 due to the scheduled outage for Unit 2. Since the two boilers are identical this will not compromise the applicability of data derived with the mobile baghouse to the full scale facility on Unit 2. This is dependent on Unit 1 burning Wyoming coal during the test program.

The following specific parameters will be studied:

1. Air-to-cloth ratio
2. Cleaning method
3. Frequency and degree of cleaning
4. Humidity effects
5. Static charge on the dust cake

The program schedule is shown in Figure 2. The two week increment allotted to each bag candidate will be flexible as will the specific daily schedule shown in Figure 3. These schedules will be modified as necessary to achieve adequate data on the more attractive bag candidates. Actual schedules will result from a co-evaluation of data on a day-to-day basis by Acurex and SWPSCo.

4.0 PERFORMANCE MEASUREMENTS

The following sections describe and qualify the data base which will be generated during the program.

4.1 Operational Data:

Utility Boiler: The following boiler data will be provided by SWPSCo. for Unit 1.

- Boiler load (MW)
- Soot blowing and ash dumping schedule
- Flue gas temperature leaving air preheater
- Coal type
- Excess air

Baghouse Facility: The following data will be provided by SWPSCo.

- Design specifications
- Cleaning parameters
- Historical pressure drop vs. time curve

Mobile Baghouse: The following data will be taken on a regular basis.

- Inlet and outlet gas temperatures
- Flow rate
- Pressure drop across bags
- Cleaning schedule
- Residual and terminal bag ΔP

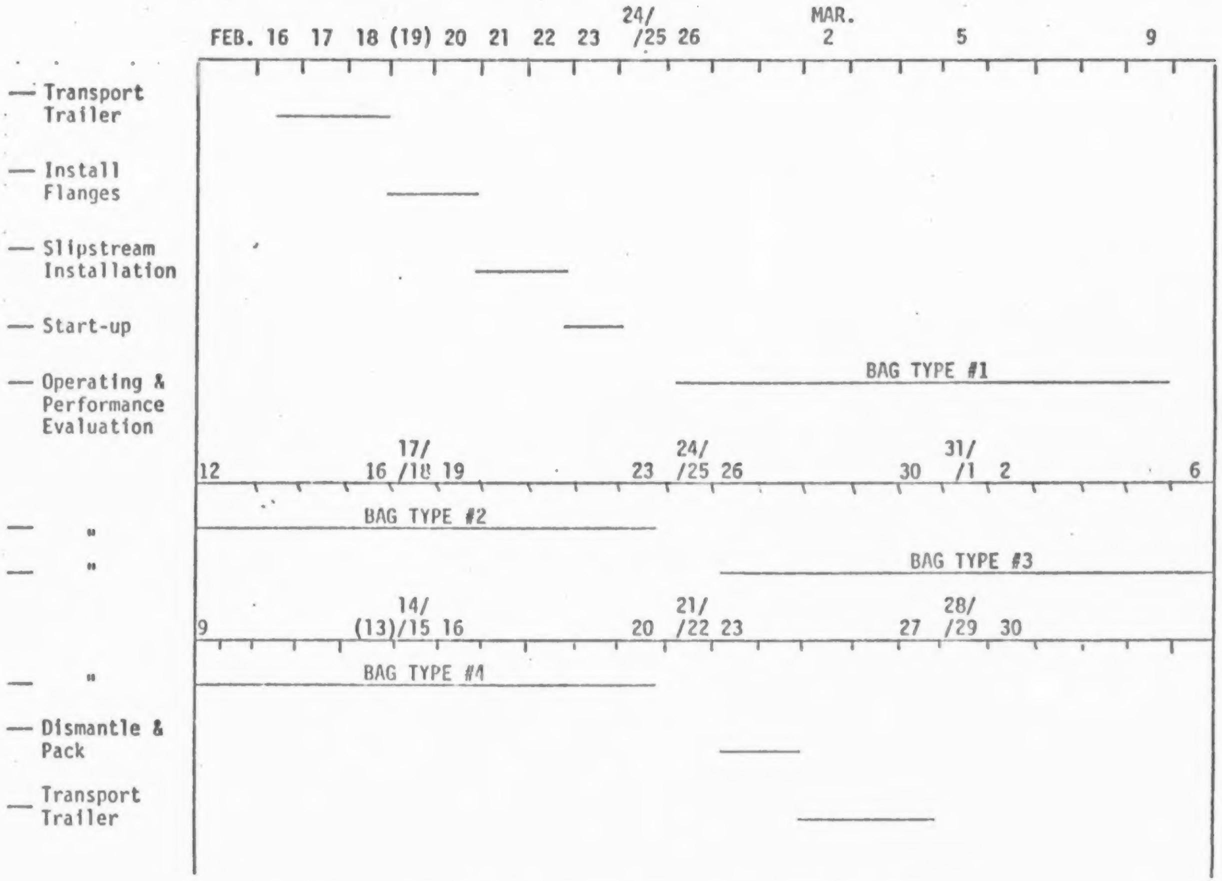


Figure 2. Program Schedule for Mobile Baghouse at Harrington Station.

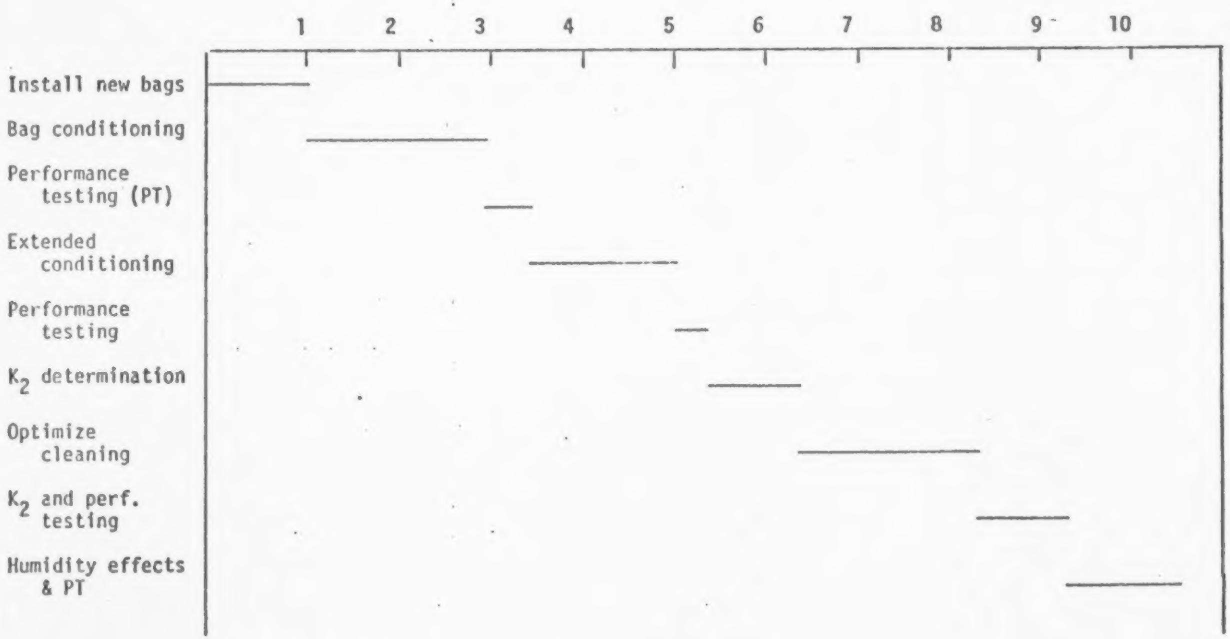


Figure 3. Typical Two Week Schedule for 1 Bag Candidate.

4.2 Particulate Concentration and Size Measurements: Particulate concentration will be made with 47mm filters. A 7-stage Brink and Andersen impactors will be used to measure the inlet and outlet size distribution, respectively. All filter and substrate material will be Reeve-Angel (934AH). Substrates will be preconditional in the flue gas to minimize anomolous weight gains.

Quality assurance measures and procedures will be performed consistant with EPA/IERL specifications.

4.3 Humidity and Static Charge: Measurement of these parameters is dependent on acquiring a measurement methodology.

4.4 Cake Resistance Coefficient: Particular attention will be given to determining the cake resistance coefficient in order to employ the fabric filtration math model for glass fabrics.

4.5 Coal and Ash Analyses: Daily coal and ash samples will be taken for possible future analysis. No plans exist at this time for specific analyses.

SWPSCo will provide results of their regular coal samples on Unit 1.

APPENDIX D. CORROSION TEST PROCEDURES

CORROSION TESTING AND USE OF CORROSION COUPONS

The test procedure given here can be used to determine relative corrosion rates of mild steel. By using coupons made from other metals it can also be adapted to test any metal, if representative coupons of that metal can be obtained and prepared.

The major value of this method is to allow us to compare the corrosivity in our various systems.

Conditions given here must be followed in detail if results of any value are to be obtained.

General Instructions for use of coupons. The following conditions must be observed.

1. Coupons must be clean, bright metal and free of oil or grease.
2. Coupons must be installed without coming in contact with hands or other source of contamination.
3. Coupon must not come in contact with metal of any kind; hanger rods are plastic-nut and bolt are 101 mylon or Teflon covered metal.
4. Flow in area where coupons are installed should be low. High flow will increase corrosion rate. Extremely slow flow rates may not maintain corrosion coupon under conditions actually representative of the system.
5. Upon removal from system, coupons must be dried and sent in for processing as soon as practicable.
6. Cards on corrosion coupons must be filled in as complete as possible and any unusual conditions noted.

SPECIAL TESTING PROCEDURES

CORROSION

7. Every other coupon will be removed after 120 to 180 days to analyse corrosion effects. All other coupons will be removed after one year exposure to gases and the coupons in back inlet and outlet will be removed when unit is shut down.

SPS Co. laboratory preparing the coupons will provide all necessary equipment for installation and will process the exposed coupons and report results.

SPECIAL TESTING PROCEDURE

CORROSION

CORROSION TEST COUPONS

PREPARATION AND EVALUATION

Coupon Material: Cold rolled mild steel - SAE 1010 low carbon ASTM D 609.

Coupon Size: Width 3". Length 6". Thickness .032 gauge. One 1/4" hole 3/8" to center from one end. Approximate weight 75 grams.

Inspection Before Preparation: Coupons are carefully inspected for excessive rusting, pitting or deformities and bad specimens are rejected. Coupons are numbered by stamping with metal dies.

Preparation for Exposure:

1. Submerge in Acetone to remove any film. Inspect for cleanliness.
2. Submerge in concentrated hydrochloric acid for 30 seconds.
3. Submerge in saturated solution of sodium carbonate for 1 minute.
4. Wash twice with distilled water.
5. Submerge in acetone solution Number 1 for 15 seconds.
6. Submerge in acetone solution Number 2 for 15 seconds and twirl until dry.
7. Store in dessicator.
8. Weight in nearest milligram and record on prepared card.
9. Wrap in clear plastic for mailing.

Cleaning and Evaluation of Exposed Coupons:

1. Carefully wipe loose material such as organic or loose rust away with soft tissue.
2. Submerge in concentrated inhibited hydrochloric acid for 1 to 2 minutes. (metal loss is 10 milligram per 1 minute while submerged in acid and must be corrected for in final calculations.)
3. Submerge in saturated solution of sodium carbonate for 1 minute.
4. Wash twice with distilled water.
5. Submerge in acetone solution Number 1 for 15 seconds.
6. Submerge in acetone solution Number 2 for 15 seconds.
7. Store in dessicator.
8. Weight to nearest milligram.
9. Examine for pitting. If present, measure three deepest pits with needle point micrometer and average.

Calculation of Corrosion Rate:

$$\text{Inches per year} = \frac{77.16^{*} \text{ X wt. loss grams}}{\text{days exposed}}$$

*Above figures are based on an average coupon with 36 square inches of exposed surface 0.0315" thick and weighing 74.5 grams.

CORROSION TEST COUPONS

PREPARATION AND EVALUATION
(continued)

Calculation of Pitting Rate:

$$\text{Inches per year} = \frac{\text{Average pit depth} \times 365}{\text{Days exposed}}$$

Note: Coupons must be handled with ivory tipped forceps during preparation for exposure and evaluation. Never touch with bare hands. Glass rod with a hook bent on one end is used for submerging coupons in solutions.

SPECIAL TESTING PROCEDURES

CORROSION

SOLUTIONS USED FOR CLEANING AND DRYING COUPONS

Concentrated Hydrochloric Acid: (Spec. gravity approx. 1.18)

Inhibited Concentrated Hydrochloric Acid - 18 mls. formaldahyde (37% HCHO) plus 387 mls. concentrated hydrochloric acid.

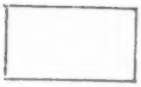
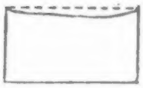
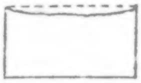
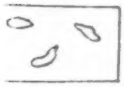
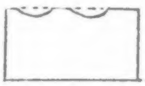
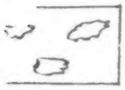
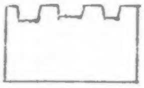
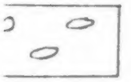
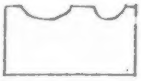
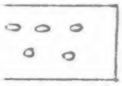
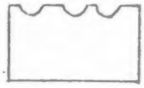
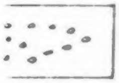
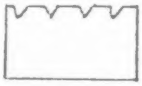
Sodium Carbonate Solution: A saturated solution of sodium carbonate and distilled water.

Acetone #1 and #2: Acetone, analytical reagent anhydrous.

SPECIAL TESTING PROCEDURES

CORROSION

CORROSION DESCRIPTION

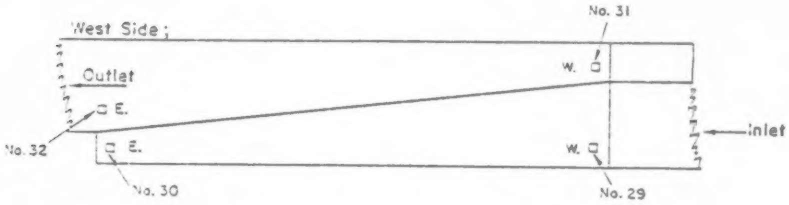
		0	0.01-0.50MPY	0.51-3.00MPY	3.00-20MPY	>20 MPY
		None Visible (a)	---	---	---	---
		---	Negligible (b)	Slight even general (C 1)	Moderate even general (D 1)	Severe even general (E 1)
		---	Negligible (b)	Slight uneven general (C 2)	Moderate uneven general (D 2)	Severe uneven general (E 2)
		---	Negligible (b)	Slight even localized (C 3)	Moderate even localized (D 3)	Severe even localized (E 3)
		---	Negligible (b)	Slight uneven localized (C 4)	Moderate uneven localized (D 4)	Severe uneven localized (E 4)
		---	Wide pits (F)	---	---	---
		---	Medium pits (G)	---	---	---
		---	Narrow pits (E)	---	---	---

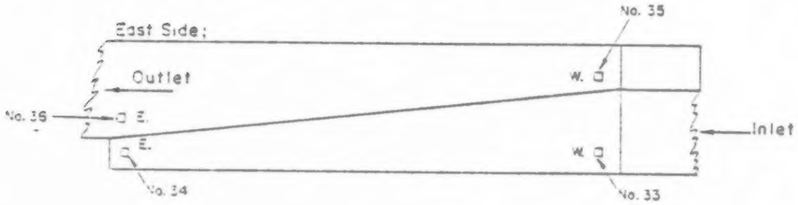
1. Before cleaning strip testers will be photographed if they appear unusual in any respect. i.e. partly eaten away, heavy deposit, etc.
2. All strip testers will be photographed after cleaning.
3. If there is negligible (or no) corrosion any staining or other unusual appearance will be repeated.
4. Large pits will be measured (depth) and reported.

LOCATION OF CORROSION COUPONS

One coupon per compartment, numbers on coupons to match numbering of compartments. (No. 1 thru No. 28)

Inlet and Outlet Ducts:


West Side;
No. 31
W.
Outlet
E.
No. 32
E.
W.
Inlet
No. 30
No. 29


No. 35
East Side;
Outlet
W.
No. 36
E.
E.
W.
Inlet
No. 34
No. 33

Total: 36

STEEL Q-PANELS

Type S .032 Cold Rolled Steel, Ground 1 side

Ground one side to 15-20 mu.
Rolled side 30-50 mu.
Clean, ready-to-use
¼" hole; corners, edges rounded
SAE 1010 low carbon steel
Panel meets: ASTM D-609
Fed. Test Std. #141, Method 2011
Packed in units of 25 panels in preservative paper, plastic bag.

Size (inches)	Stock No.	Price per 100 Panels in quantities of						
		100	250	500	1000	2500	5000	10.000
2¼ x 5½	S-25W	14.00	13.00	12.50	12.00	11.50	11.00	10.50
3 x 5	S-35	13.00	12.00	11.50	11.00	10.50	10.00	9.50
3 x 6	S-36	13.50	12.50	12.00	11.50	11.00	10.50	10.00
3 x 8	S-38	14.50	13.50	13.00	12.50	12.00	11.50	11.00
3 x 9	S-39	15.50	14.50	14.00	13.50	13.00	12.50	12.00
4 x 6	S-46	14.50	13.50	13.00	12.50	12.00	11.50	11.00
4 x 8	S-48	15.50	14.50	14.00	13.50	13.00	12.50	12.00
4 x 12	S-412	17.50	16.50	16.00	15.50	15.00	14.50	14.00
6 x 12	S-612	22.50	21.50	21.00	20.50	20.00	19.50	19.00

Type R .032 Cold Rolled Steel, Matte finish

Same steel as Type S without grinding.
Both sides cold rolled to 30-50 mu.
Steel washed before annealing.

Size (inches)	Stock No.	Price per 100 Panels in quantities of						
		100	250	500	1000	2500	5000	10,000
2¼ x 5½	R-25W	12.50	11.50	11.00	10.50	10.00	9.50	9.00
3 x 5	R-35	11.50	10.50	10.00	9.50	9.00	8.50	8.00
3 x 6	R-36	12.00	11.00	10.50	10.00	9.50	9.00	8.50
3 x 8	R-38	13.00	12.00	11.50	11.00	10.50	10.00	9.50
3 x 9	R-39	13.50	12.50	12.00	11.50	11.00	10.50	10.00
4 x 6	R-46	13.00	12.00	11.50	11.00	10.50	10.00	9.50
4 x 8	R-48	13.50	12.50	12.00	11.50	11.00	10.50	10.00
4 x 12	R-412	15.50	14.50	14.00	13.50	13.00	12.50	12.00
6 x 12	R-612	19.50	18.50	18.00	17.50	17.00	16.50	16.00

Type QD .020 Cold Rolled Steel, Bright finish

Rolled smooth to 8-12 mu.
Steel washed before annealing.
Low cost, clean, ready-to-use
¼" hole; corners, edges rounded
SAE 1010 low carbon steel.
Packed in units of 40 panels in preservative paper, plastic bag.

Size (inches)	Stock No.	Price per 100 Panels in quantities of						
		100	250	500	1000	2500	5000	10,000
3 x 5	QD-35	3.00	7.50	7.00	6.50	6.00	5.50	5.00
3 x 6	QD-36	8.50	8.00	7.50	7.00	6.50	6.00	5.50
3 x 8	QD-38	9.50	9.00	8.50	8.00	7.50	7.00	6.50
3 x 9	QD-39	10.00	9.50	9.00	8.50	8.00	7.50	7.00
4 x 6	QD-46	9.50	9.00	8.50	8.00	7.50	7.00	6.50
4 x 8	QD-48	10.50	10.00	9.50	9.00	8.50	8.00	7.50
4 x 12	QD-412	12.50	12.00	11.50	11.00	10.50	10.00	9.50

Type HR .064 Hot Rolled Steel

16 gauge hot rolled, hydrochloric pickled steel.
Clean, ready-to-use, with ¼" hole and edges, corners rounded – packed in units of 10 panels.

Size (inches)	Stock No.	Price per 100 – Quantity of			
		100	250	500	1000
3 x 6	HR-36	17.00	16.00	15.50	15.00
4 x 8	HR-48	21.00	20.00	19.50	19.00
4 x 12	HR-412	25.50	24.50	24.00	23.50
6 x 12	HR-612	32.00	31.00	30.50	30.00

Type HRB .064 Sandblasted HR Steel

Same steel as Type HR.
Sandblasted to 1-2 mil profile.
Packaged to prevent rust indefinitely.

Size (inches)	Stock No.	Price per 100 – Quantity of			
		100	250	500	1000
3 x 6	HRB-36	32.00	30.00	29.00	28.00
4 x 8	HRB-48	42.00	40.00	39.00	38.00
4 x 12	HRB-412	57.00	55.00	54.00	53.00
6 x 12	HRB-612	75.00	73.00	72.00	71.00

Type D .010 CR Steel, Smooth finish

.010 SAE 1010 steel, rolled to 8-12 microinches.
Clean, ready-to-use, for batch records, shading, flexibility tests or samples.

Size (inches)	Stock No.	Price per 100 – Quantity of			
		100	250	500	1000
3 x 6	D-36	7.00	6.00	5.50	5.00

Type DT .010 Electrolytic Tinplate

.010 CR steel, tinplated with bright reflow finish, conforms to Fed. Test Std. #141, Method 2012, Preparation of Tin Panels.

Size (inches)	Stock No.	Price per 100 – Quantity of			
		100	250	500	1000
3 x 6	DT-36	7.00	6.00	5.50	5.00

THE Q-PANEL COMPANY 15610 INDUSTRIAL PARKWAY · CLEVELAND, OHIO 44135 · PHONE (216) 267-9200

CORROSION COUPONS WEIGHTS
for
HARRINGTON STATION UNIT 2
BAGHOUSE

3" x 6" Q Panels *

Coupon Number	Weight	Coupon Number	Weight
1	72.1150	21	71.1887
2	71.4471	22	71.4255
3	72.4578	23	71.2358
4	71.4497	24	75.8967
5	71.3295	25	75.8130
6	71.0409	26	72.4751
7	71.4606	27	75.9499
8	71.5762	28	75.5271
9	71.1310	29	75.6703
10	71.3176	30	76.3859
11	71.3980	31	68.1900
12	71.1820	32	77.8147
13	71.5155	33	78.2758
14	71.7493	34	78.3320
15	71.7500	35	78.2010
16	76.3133	36	76.9453
17	74.1110	37	76.7273
18	74.3495	38	77.4247
19	73.1115	39	68.2680
20	73.9455	40	68.1907
		41	68.1615

Note: Prepared 2-28-78 by Mario Tinajero

* Q Panel Type S 3"x6"x.032"
SAE 1010 low carbon steel
ASTM D-609 Specs
Acid cleaned and dried as in standard corrosion coupon procedure before weighing

APPENDIX E. RTI ELECTROSTATIC REPORT

RTI/1644/02-01S

BAGHOUSE ELECTROSTATICS AT HARRINGTON NO.2

Prepared by

R. P. Donovan
M. B. Ranade

Research Triangle Institute
Energy & Environmental Research Division
P. O. Box 12194
Research Triangle Park, N. C. 27709

Grant No. R805897-01-0

Prepared for

U. S. Environmental Protection Agency
Industrial Environmental Research Laboratory
Research Triangle Park, N. C. 27711

March 1979

INTRODUCTION

This report summarizes two diagnostic measurements made at the Harrington No.2 baghouse on March 8-9, 1979. The purpose of these measurements was to assess the role of electrostatic forces in the bag cleaning problems being encountered at Harrington. Reports of noticeable electrical discharges accompanying probe insertion into the inlet ducts at Harrington had led to speculation that electrostatic effects might be hindering dust removal during bag cleaning.

Using measurement techniques previously developed as part of the EPA in-house work in fabric filtration, spot checks of inlet dust charge and bag charge were made. From these measurements several interactions have been postulated but the only firm conclusion yet possible is that electrostatic effects cannot be ruled out as a cause of the unsatisfactory dust release from the bags. Additional measurements, not necessarily very extensive, are needed; an experimental program to collect the needed data expeditiously and cheaply is outlined.

SUMMARY OF MEASUREMENTS AT HARRINGTON

(1) A "cage" voltage measurement of a silicone-graphite bag adjacent to the viewport of compartment No.22. The cage consisted of a 40-inch section of Type 430 stainless steel screen (0.0075-inch wire, 24 mesh) wrapped around the bottom of the bag. A lead from the cage to a ceramic feed-through placed in the compartment door jamb coupled the cage electrically to an electrometer outside the compartment.

(2) An inlet dust charge/mass measurement. A 5-minute dust sample was drawn through an electrically isolated Millipore filter. Current flow during the sample period was monitored as the dust sample was collected. Total charge collected is the integrated sample current which then can be divided by the sample mass to obtain a charge/mass ratio.

Outlet sampling, tentatively planned to be performed similar to the inlet sampling, was not carried out. Because of the low dust concentration in the outlet, the charge/mass measurement may be difficult. In any event it will be time consuming.

RESULTS

(1) Cage Voltage

(a) Bag cage resistance prior to compartment gas flow: 4-5 x 10^8 ohms.

This resistance is simply that measured between the cage and electrical ground at ambient temperature and with deflated bags. The resistance is determined primarily by bag electrical resistance but could also be affected by any leakage to ground from the wire lead to the electrometer (such as at the compartment wall feed-through). The latter is assumed to be negligible with respect to 4-5 x 10^8 Ω so that this value probably represents bag electrical resistance. It's a rather low value and could mean that the silicone/graphite finish does reduce the electrical resistance of the bag significantly, although not enough to eliminate cage charging completely as will be discussed next.

(b) Cage voltage during operation.

Initial gas flow through the compartment generated a large negative voltage on the cage (-1000 volt to -1300 volt appeared briefly on the cage). This signal settled down to values generally between -200 volt and -400 volt. During cleaning, apparently at the cessation of gas flow, the cage voltage moved to large positive values (~+ 1000 v); decayed to near zero volts during pause and shake (or displayed a small positive voltage), and generally showed a large, rapid buildup of negative voltage as gas flow resumed. This large (sometimes as large as -1000 volts) signal slowly decayed to the -200 to -300 volt range where it drifted slowly up and down until the next cleaning cycle.

While this pattern was the most common, it was not the only one seen. On occasions a positive voltage appeared during the filtration cycle for short periods of time. Once when the cleaning cycle started with a positive voltage, the cage swung to a negative value--presumably at the cessation of gas flow. These observations are consistent with a bipolar, but predominantly negative charge on the bag. What the cage detects is net bag charge adjacent to the cage. What the inlet sample (discussed below) measures is net dust charge. Although related, bag charge and dust charge are not necessarily the same.

(c) Cage current

Cage current measurements were mostly negative but very unstable, oscillating rapidly between +1 or +2 nA to -8 to -10 nA at a frequency of 1 to 2 Hz. Current could not be accurately measured because the bag resistance was probably lower than the electrometer resistance. Because of the relatively low bag resistance, the cage current is better deduced from measurements of cage voltage and resistance:

$$I = \frac{400 \text{ volts}}{4\times10^{8}\ \Omega} = 1\times10^{-6}\text{A}.$$

This value of current agrees adequately with the current calculated from the Q/m of the dust (see below) and the rate of dust collection.

(2) Inlet Dust Charge

A 5-minute probe sample drawn from the inlet to the East baghouse compartments collected 8.944 mg of flyash at a flow rate of 4.9 ℓ/minute. At the same time the current flow was approximately 5×10^{-11} A negative. This current level was not steady but varied from an initial value of less than 10^{-11} A for the first 30 or so seconds up to a value in excess of 5×10^{-11} A and decayed slowly to a value slightly less than 5×10^{-11} A. The initial low current could be attributed to probe dead space, since the pump and the sampling time started simultaneously.

Rough averaging of the current and mass values yields an average charge/mass value of 1.7 μC/g.

This value of charge/mass is of the same order of magnitude as that of flyash exiting the first stage of a poorly operating electrostatic precipitator. Calculations with typical conditions measured at the Environmental Protection Agency's electrostatic precipitator yielded a charge/mass value of 0.74 μC/g with the following size dependence:

D(μm)	Q/M(μC/g)
0.1	1706
1.0	21.63
5.0	1.620
10.0	0.665

DISCUSSION/INTERPRETATION

The dust entering the baghouse is charged as the inlet measurements show. With gas flow the cage also acquires a charge which decays rapidly when the dust flow stops. During the shake cleaning, the cage voltage is low--just as the inlet probe current is low when not drawing gas flow through the sampling chamber. Drawing ambient air through the inlet probe sampler drops the current several orders of magnitude and changes the sign of the current to positive. Cage current, on the other hand, is mostly negative but very erratic.

While no measurement of bag capacitance was made, it's almost certain to be less than 10^{-9}F and hence the time constant of the cage is likely to be on the order of 1 second or less. That the cage voltage disappears or becomes small when gas flow stops suggests that the charge source is the flowing dust and that the charges are sufficiently well coupled to ground by the fabric to disappear shortly after gas flow stops. While little charge seems present during shake cleaning, this observation does not rule out electrostatics as a source of dust retention. Electrostatic forces during the filtration period can initiate bonds which persist after the electrostatic forces disappear, as in electrostatic sealing technology.* If such permanent bonding accompanies fabric filtration at Southwest, adding humidity or taking other charge-dissipating steps will not solve the problem for bags already coated. Only on new fabrics would the charge-dissipating step be effective.

The silicone/graphite coating on the fiberglass, while not highly conductive, does seem to reduce bag electrical resistivity. Teflon-coated fiberglass bags would probably be of much higher resistivity and would retain electrical charges longer. Given longer electrical time constant, the charge sheet would then be retained throughout the cleaning cycle, which doesn't seem to happen with the silicone-graphite bags.

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*Electrostatic glass to silicon seals are formed by applying a dc field across the glass/silicon interface. The surfaces apparently deform and flow together under the high interfacial field and form bonds which remain stable after the external field is removed or even reversed in polarity.

One interpretation then of the observed cage voltage is that the dust-laden gas acts as a charge source which creates a voltage, V_E, on the inside surface of the bag. This voltage is RC-coupled to the measured cage voltage as indicated in Figure 1. When the gas flow is on, V_E takes on a negative value, producing a negative voltage on the screen cage. If V_E drops to zero when the gas flow stops, a positive voltage appears on the cage (Figure 2) because of the capacitive coupling postulated in Figure 1.

While this prediction does account for the switch in cage voltage polarity actually observed to accompany gas flow shutoff, it assumes bag charge dissipates rapidly when the gas flow stops. Fabric resistance alone would support this assumption but an alternative model proposed by Phil Lawless of the RTI/EPA electrostatic precipitator research team introduces the role of dust cake electrical resistance and its influence on the electric charge/field distribution. From ESP technology it is known that low resistivity dusts adhere poorly to the collection plates and actually cause reentrainment problems because of early dust release from the plates in an unagglomerated, basically as captured size distribution. (This low resistivity dust problem is a problem at the opposite end of the dust resistivity spectrum from the better publicized high resistivity dust degradation of ESPs.) That one way of correcting this undesirable action in ESP operation is to increase the dust resistivity suggests to Lawless that the converse--lowering the dust resistivity with respect to the fabric resistivity (or raising the fabric resistivity with respect to the dust resistivity) so as to facilitate removal--may be worth investigating. Schematically, his model is shown in Figure 3. The key feature of this model is that the greatest voltage drop between the inside surface of the dust cake (the freshly deposited surface) and electrical ground occurs across the dust cake itself, holding the dust cake together electrostatically during both the filtration and the cleaning cycles. Furthermore the external screen cage voltage is only a fraction of the actual dust cake voltage because of the low electrical resistivity of the fabric relative to the dust cake.

An easy corrective action suggested by this model is simply to raise the electrical resistivity of the fabric so that the greatest voltage drop occurs across it rather than the dust cake (Figure 4). This action will also increase the cage voltage substantially but, if the electric field redistribution thereby achieved reduces the dust cake cohesiveness, bag cleaning should become easier. This model identifies the ratio of dust resistivity to fabric resistivity as an important design parameter and speculates that one potential solution to the bag cleaning problem at Harrington is to use bags of higher electrical resistivity, i.e., teflon-coated fiberglass.

Additional implications are that the charges on the inside of the bag do not dissipate rapidly when dust flow stops but discharge only slowly with respect to the cleaning time through the high resistivity dust cake. A detecting probe inside the bag would be valuable for measuring this postulated higher interior voltage, especially during the cleaning cycle.

The origin of the positive cage voltages seen when gas flow stops are not readily accounted for by this model, although capacitive decoupling between the cage and the charge sheet during cleaning could induce this type of signal $\left(dV = \frac{CdQ - QdC}{C^2}\right)$.

Recap

Two interpretations of the observed cage voltage have been outlined. The first ignores the electrical properties of the dust cake and assumes that the bag charge dissipates rapidly once gas flow ceases. The second postulates that the electrical resistance of the dust cake dominates both the cage voltage measurement and the electric field distribuiton in both the filtration and the cleaning mode and that the dust borne charges are not rapidly dissipated because of the high electrical resistance of the dust cake.

These two alternative models prescribe different corrective actions--for example, the first would recommend low fabric electrical resistivity to minimize electrical forces on the dust cake while the second recommends just the opposite. Additional data, including measurements made with an interior, center line probe, are needed to resolve these alternative explanations and corrective actions.

CONCLUSIONS

(1) Perhaps the most significant conclusion of the brief sampling is that electrostatic forces should not be ruled out as a source of dust adhesion between the dust and the fabric. Voltage signals of the order of magnitude observed at Harrington have degraded bag performance in EPA pulse jet studies. Assuming similar bag dimensions and dielectric constant implies a dust charge sheet at Southwest comparable to that that has caused observable effects at the EPA in-house facility.* While not proving an electrostatic effect, our measurements caution against discarding this possibility, as is the common industry practice.

(2) Inlet sampling estimates charge/mass to be 1.7 μC/gm, a high value for flyash that has not been deliberately charged. Other researchers have shown that deliberately charged dust produces a dust cake of lower pressure drop than the cake formed from the same dust without a charge. These results reported by others invariably have been for short term exposures (two weeks or less); the Harrington experiences, a long term effect, may be another dimension of the charged dust/fabric interaction not previously recognized.

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*This conclusion based on EPA in-house measurements is not really firm as implied here. The proposed mechanisms of induced degradation are still being verified.

RECOMMENDATIONS

Assuming that the crucial question is to determine if the dust cleaning problem at Southwest is primarily electrostatic, the need now is for a demonstration or experiment that unambiguously relates bag charge/unit area to dust cleaning efficiency, bag weight/unit area, pressure drop, or some other quantitative measure or combination of measurements of dust removal. Once such a relationship is established, then the study of the origin of the charge and how to reduce it, its dependence on gas flow, dust concentration, dust composition, fabric type, etc., become of more than academic interest.

Conversely, failing to show a bag charge-bag weight correlation, justifies looking elsewhere for Southwest's answers and leaving electrostatics to others.

In general terms the recommended course of action is to:

(1) Determine if electrostatic effects are significant;

(2) If so, attempt to understand the electrostatic interaction ("model" the electrostatic interaction);

(3) Based on the model developed in (2), define a remedy to eliminate the undesirable consequences of electrostatics on the Harrington baghouse.

To proceed we recommend:

(1) Fabrication of apparatus to measure cage voltage routinely. Perhaps the simplest and most lasting arrangement is one in which a cylindrical screen cage is mounted on an electrically insulating base, composed of two separable halves which can be hooked together around a bag but perferably not touch or restrict the bag motion.

(2) In addition fabrication and installation of an electrically isolated conductive rod or wire positioned inside the bag and along the bag centerline. During filtration this electrode detects both incoming dust charge and accumulated dust cake charge. These charge components may not be easy to separate. But during the cleaning cycle, the dust flow stops. Then the probe can be momentarily discharged and used to detect dust cake charge during the cleaning cycle.

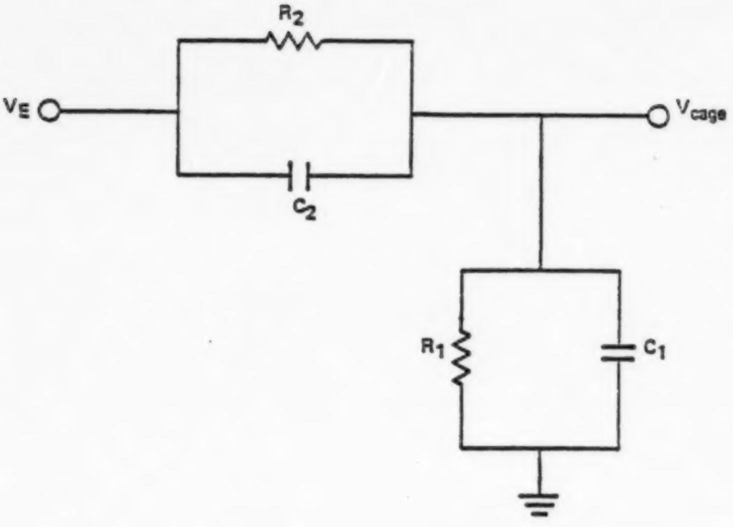
The design of this centerline probe could take several tacks, including the suggestion by John Perry to suspend a wire from the top cap. Perhaps an approach more compatible with the bottom screen cage is to construct a support that slips over the thimble and fastens to it. By two or three arms, this support could hold a 40-inch rod on the bag centerline. The rod and its contact/lead wire must be electrically insulated from the thimble.

(3) Installation of an AC corona charger in the dust inlet of one compartment so as to be able to neutralize the incoming dust charge. Assuming that the dominant source of bag electrostatic charge is that which the dust brings with it, the removal or neutralization of this charge would yield electrostatic charge-free operation. Both the centerline rod and the cage screen should pinpoint the corona parameters that produce minimum charge at the bag.

(4) Collection of screen cage voltage and centerline rod voltage for both high resistivity bags (teflon coated fiberglass) and lower resistivity bags (silicone-graphite coated fiberglass), with and without dust charge neutralization. Fabric resistivity and flyash resistivity should be measured, if possible, for later use in the modeling of the interaction.

Completing these steps would furnish sufficient information for assessing the significance of electrostatics at Harrington. Indeed an adequate model and appropriate corrective action may become self-evident in the course of these "initial" actions.

Most likely these modifications will be easier to carry out in the pilot baghouse than in the main unit. Such implementation should not compromise the validity of the results.



R_2
V_E
V_{cage}
C_2
R_1
C_1

Figure 1. Simple Equivalent Circuit

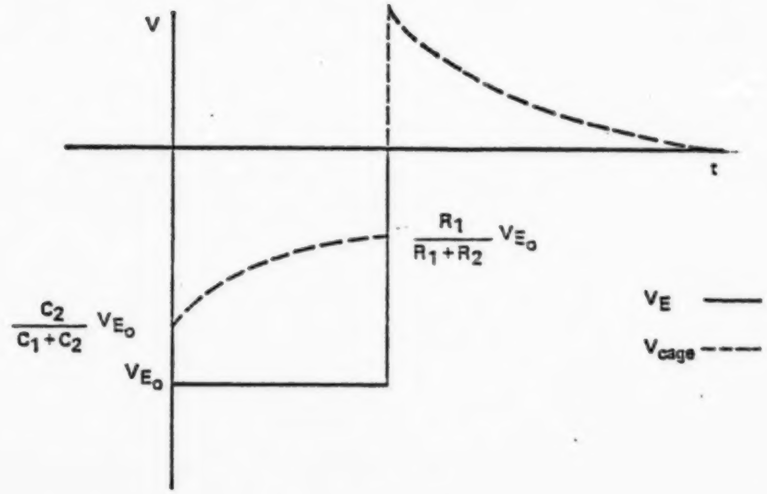


Figure 2. Circuit Response

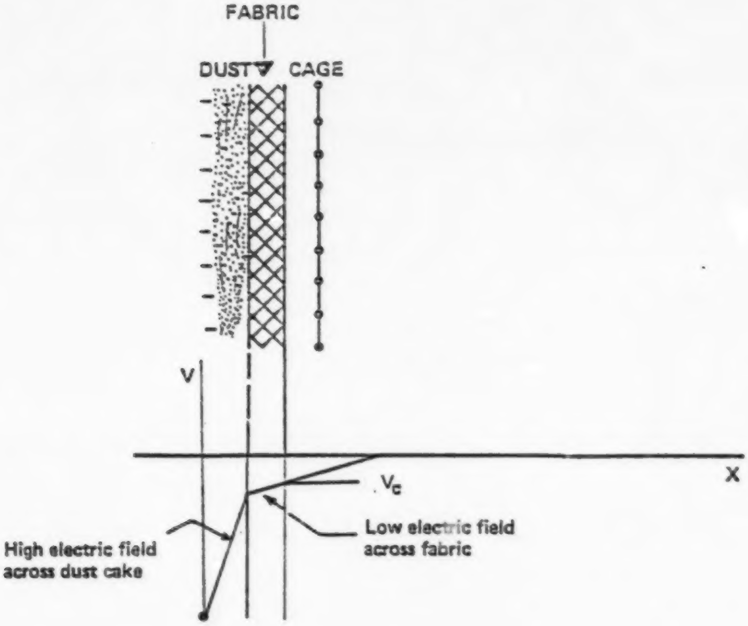

FABRIC
DUST
CAGE
V
X
V_c
High electric field across dust cake
Low electric field across fabric

Figure 3. Lawless Dust Cake Model for Interpreting Cage Voltage

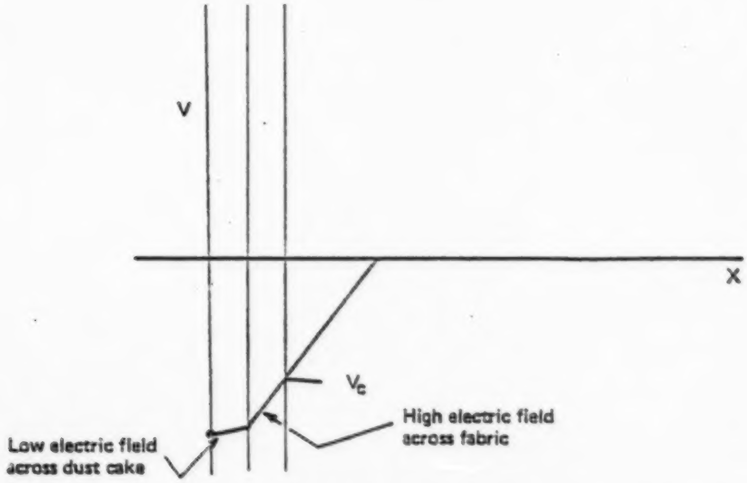

V
X
V_c
High electric field across fabric
Low electric field across dust cake

Figure 4. Desired Electric Field Distribution